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EXTENDED MEASUREMENTS OF AERODYNAMIC STABILITY AND LIMB DISLODGEMENT FORCES WITH THE ACES-II EJECTION SEAT

Fred W. Hawker, et al

Payne, Incorporated

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Aerospace Medical Research Laboratory

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EXTENDED MEASUREMENTS OF AERODYNAMIC STABILITY AND LIMB DISLODGEMENT FORCES WITH THE ACES II EJECTION SEAT

PAYNE, INC.
1910 FOREST DRIVE
ANNAPOLIS, MARYLAND 21401

JULY 1975

Approved for public release; distribution unlimited

AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

NOTICES

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 80-33.

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

HENNING E. VON GIERKE
Director
Biodynamics and Bionics Division
Aerospace Medical Research Laboratory

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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20. Abstract

seat/occupant combination was taken with the dummy subjects. The limb dislodgement results are complementary to earlier tests at low pitch angles and show general reductions in magnitude as the pitch angle is increased. There is good agreement between the previous tests with live subjects and this series. The seat was found to be slightly stable in pitch over the range -15 to +15 degrees, becoming unstable at larger angles. This holds for the entire range of yaw angles, though the effect is very slight in the sideways presentation. The seat was unstable in yaw in all forward facing attitudes (±40° yaw) over all the pitch range tested (-15° to +60°). The general form of the pitching and yawing moment curves is not changed by recomputing the moments for displacements of the CG two inches rearward, up, forward, and down, successively. There is considerable change in absolute value of the moments, but the static stability is little affected.

PREFACE

This report was prepared in partial fulfillment of Contract No. F33615-74-C-4015. The research was accomplished by Payne, Incorporated, 1910 Forest Drive, Annapolis, Maryland 21401. Peter R. Payne was the Principal Investigator.

The Air Force Technical Monitor was James W. Brinkley of the Impact Branch, Biodynamics and Bionics Division of the Aerospace Medical Research Laboratory. The work was performed in support of Project 7231, "Biodynamics of Aerospace Operations," Task 723106, "Impact Exposure Limits and Personnel Protection Criteria." This portion of the research conducted under Contract F33615-74-C-4015 was conducted to provide data applicable to new aircraft cockpit configurations utilizing reclined ejection seats. This phase of the contract research program was funded by laboratory director's funds.

Acknowledgement is made of the participation of the University of Maryland Wind Tunnel Staff in the operation of the tunnel, reduction of the balance data and giving practical help in many ways during the experiments.

A laboratory
M director's
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SUMMARY

The ACES-II seat was mounted in a wind tunnel in various attitudes of pitch, in the range -15 to +60 degrees, and yaw in the range zero facing forward to complete about face at 180 degrees. The hand and foot rests were equipped with means to measure dislodgement forces rearwards and outwards in each case. Overall forces and moments were measured at the seat mount. The pitching, yawing, and rolling moments were referred to seat axis passing through the nominal center of mass (CG) of the body-seat combination. All force and moment data in this report is presented with respect to body axes.

Human subjects were used as seat occupants for gross force and moment data on the seat/occupant combination, as well as the limb dislodgement measurements. The yaw angle was restricted to 0 to 30 degrees during this phase. Anthropomorphic dummies (small, 5%; and large, 95%) were used for the extended range of yaw angles around to 180 degrees. Only gross force and moment data for the seat/occupant combination was taken with the dummy subjects due to the stiffness of the limb joints.

The limb dislodgement results are complementary to earlier tests at the low pitch angles and show general reductions in magnitude as the pitch angle is increased. In general, there is good agreement between the previous tests with live subjects and this series, with the averages of the live subjects generally falling between the envelope defined by the 5% and 95% anthropomorphic dummies.

Static stability of the seat in the two angular modes (pitch and yaw) is indicated by the partial derivative of pitching moment with respect to pitch angle, yawing moment with respect to yaw angle. From plots of the data, the seat is slightly stable in pitch over the range -15 to +15 degrees, becoming unstable at larger angles. This holds for the entire range of yaw angles, though the effect is very slight in the sideways presentation. The seat is unstable in yaw in all forward facing attitudes (±40° yaw) over all the pitch range tested (-15° to +60°).

The general form of the pitching and yawing moment curves is not changed by recomputing the moments for displacements of the CG two inches rearward, up, forward, and down, successively. There is considerable change in absolute value but the static stability is little affected.

INTRODUCTION

Scope of the Experiment

The work described in this report was complementary to a program of measurements made in the preceding year on the F-105 ejection seat and, to less extent, on the ACES-II seat as used in the present series. This work was reported in Reference 1.

In the previous work, a comparison was established between the two seats in regard to the limb dislodgement forces. These are the aerodynamic forces tending to tear the hands, knees and feet from their "stowed" positions as provided by the seat design, thus initiating the dangerous 'flailing' movement of the limbs. A considerable difference, not readily predictable, was observed between the two seats in these respects. Additionally, some measurements of forces lifting the helmet were made. The investigation included measurement of the overall forces and moments acting on the seat-occupant combination, from which an assessment was made of the static stability of the seats in the two directions, pitch and yaw, at or around the attitudes prevalent in the actual ejection sequence. In a review of data on these and other seats, a strong family resemblance was noted in most respects except pitch.

The objectives of the present work with the ACES-II seat were:

1. To gather limb dislodgement force data at larger pitch angles than previously measured.

2. To measure helmet lift, with and without a loss preventer device.

3. To measure the overall forces and moments over an extended range of pitch and yaw attitudes, using 5% and 95% dummies successively for purposes of investigating occupant size as a variable.

4. To confirm previous data.

Additionally, the effects of CG displacement were to be studied by analysis of the force and moment data. As a qualitative study, the evaluation of flail avoidance nets over the extended range of pitch was undertaken by a test subject, Major Ray Madson of the Aerospace Medical Research Laboratory.

The tests were made in the wind tunnel at the Glenn L. Martin Institute of Technology at the University of Maryland under its Director, Donald S. Gross, during the month of May 1974.

Test Facilities and Equipment

The wind tunnel is of the single return type with a rectangular working section 7.75 feet high by 11.04 feet wide. The tunnel is vented at the working section to house ambient pressure, establishing the pressure reference datum. Dynamic pressure ($q = \frac{1}{2} \rho u^2$) at maximum tunnel operating speed is 135 lb/ft^2, corresponding to a speed of 337 ft/sec.

The tunnel is particularly suitable for tests with live subjects, since the test section accommodates a human figure, plus ejection seat, for less than 10% blockage and with adequate clearance above and below. The section is well lighted and has glass viewing panels on either side and above, so that the subject is under observation from the control room and additional vantage points. Voice communication is available but is hardly practicable during the test because of the high noise levels generated at the subject's helmet. Voice communication up to start, and immediately after shut-down, with a code of digital signs and head movements during the running, were found to be sufficient for all necessary purposes. As a safety measure, the test subject was provided with a push-button switch, which, if released, would activate shutdown in an emergency.

Forces and Moments Acting on the Seat Assembly

The seat was mounted on a pedestal attached to the force and moment balance platform in the tunnel floor. Forces and moments on the model are transmitted by mechanical linkages to the six component balance system located beneath the test section. The balance is automatic and displays six-component data at the tunnel operator's position at the central console and on a lighted number panel for plotting. All the indicated data are automatically recorded in a printout and on IBM punched cards.

Force and Moment Measurement

1. Direction of Force Measurement

   a. Lift . . . . . Vertical with respect to tunnel center line.

   b. Drag . . . . . Horizontal (fore and aft) with respect to tunnel center line.

   c. Side Force . . Horizontal and perpendicular to fore and aft tunnel center line.

2. Axes of Moment Measurement

   a. Pitching Moment . . . Horizontal and through the front model support trunnion axis, at 0° yaw angle.

b. Rolling Moment . . . Horizontal with respect to tunnel center line - intersecting pitching moment axes on tunnel center line.

c. Yawing Moment . . . . Vertical through center line of tunnel - intersecting pitching moment axis at front model support trunnions.

Balance and Support System Limitations

Force and Moment Measurement of Basic Unit

Component	Range	Accuracy
Lift (lb)	0 to ±5000	±0.50 lb
Drag (lb)	0 to ±500	±0.10 lb
Side Force (lb)	0 to ±1000	±0.10 lb
Pitching Moment (ft-lb)	0 to ±1000	±0.20 lb
Rolling Moment (ft-lb)	0 to ±1000	±0.20 lb
Yawing Moment (ft-lb)	0 to ±1000	±0.20 lb

Accuracies apply to loadings of less than 10% of forces and 20% of moments. Loadings in excess of these percentages can be measured with an accuracy of one tenth of one percent (0.1%). The accuracy of the tunnel velocity is ±0.5%.

The tunnel services include programs for transfer of force and moment data from tunnel axes to body axes (or indeed any other workable system of coordinates). Figure 2 is a sketch showing the seat displaced through an angle of yaw (azimuth) and pitch (elevation). In most aerodynamic studies, these angles are small and it is customary to refer to wind axes through the body center of mass or some other geometrically convenient point as origin. In the present study, body axes are employed for gross forces and moments, with the origin at an arbitrarily defined CG point shown in Figure 1.

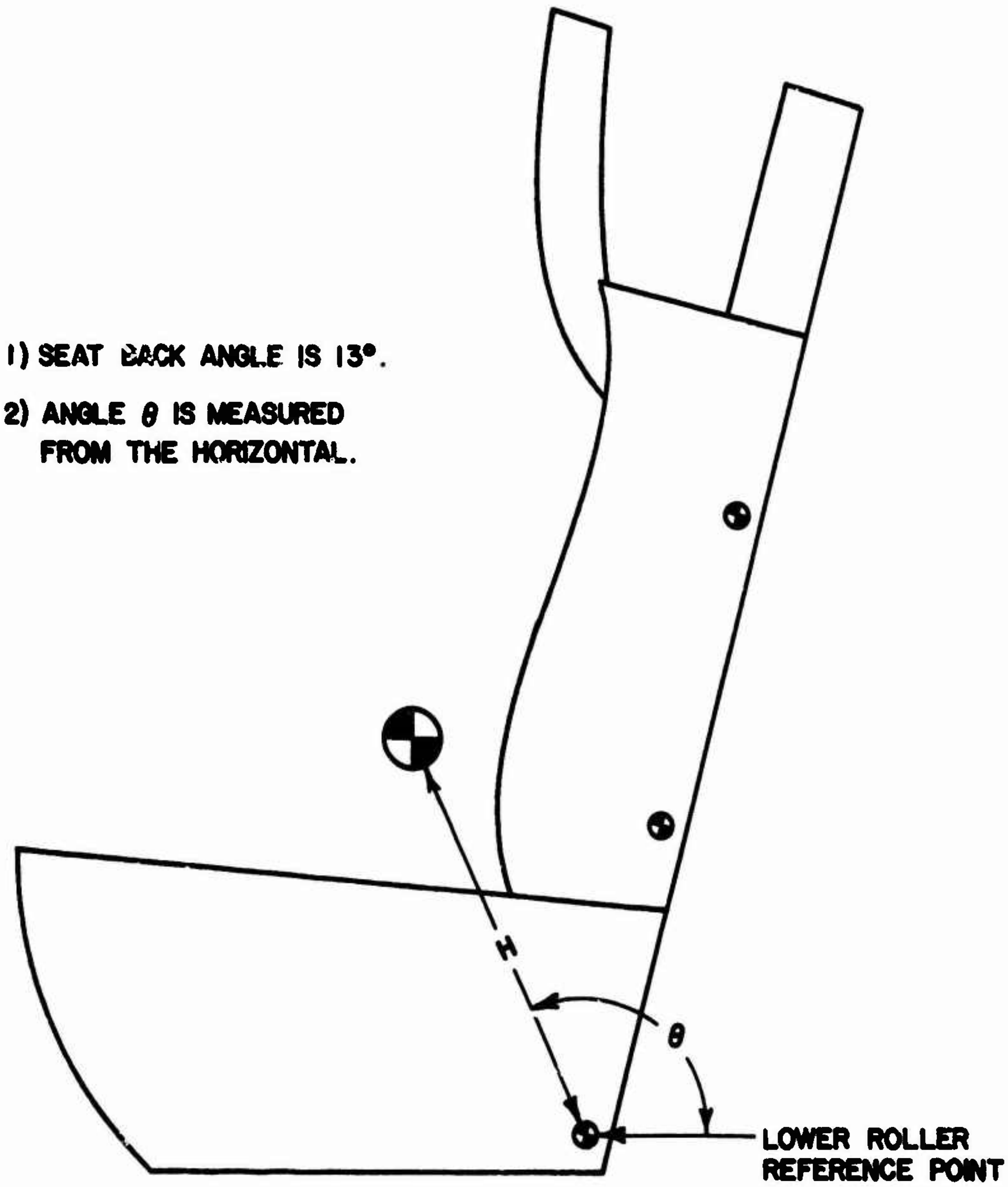
Local Force and Pressure Measurements

The tunnel instrumentation provided 58 automated data channels, including ten galvanometer systems linear to 600 Hz. Fifteen of these channels were used to record limb segment and helmet forces and moments from pressure or strain transducers mounted on the seat assembly. As with the force and moment balance data, the local measurements on these channels was automatically punched on IBM cards. Any six channels on this system could be switched to dynamic recording, linear to 150 Hz, if examination of transients in real time should be required.

NOTES:

1) SEAT BACK ANGLE IS 13°.

2) ANGLE θ IS MEASURED FROM THE HORIZONTAL.



CG LOCATIONS IN POLAR COORDINATE FORM FOR SEAT-MAN COMBINATION

OCCUPANT	H	θ
5%	1.692	110.9
50%	1.669	113.1
95%	1.649	115.4

FIGURE 1 CENTER OF GRAVITY LOCATIONS USED IN DATA REDUCTION.

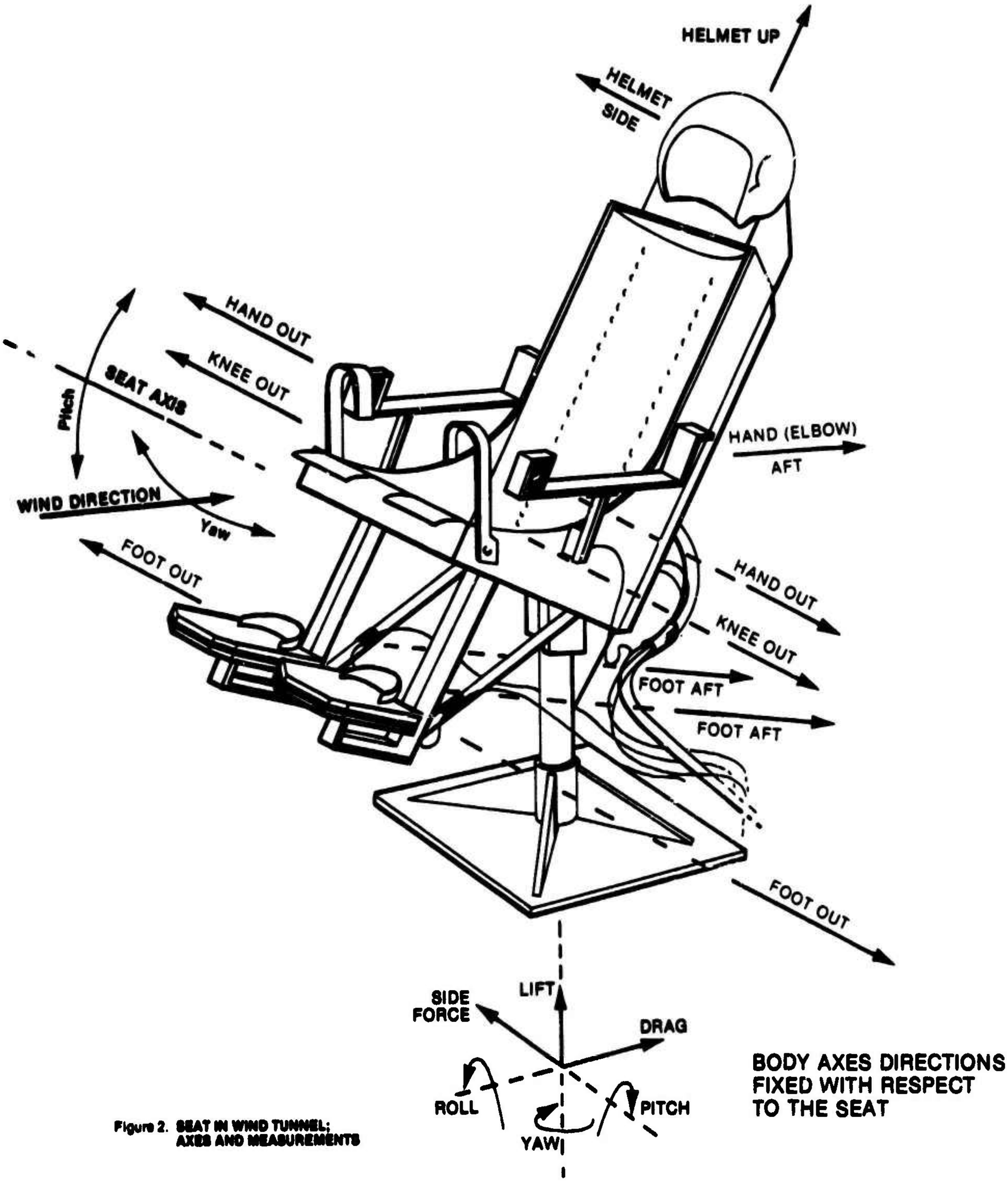


Figure 2. SEAT IN WIND TUNNEL;
AXES AND MEASUREMENTS

Figure 2 shows the locations of the limb dislodgement force measurements. The measured quantities are, on the leg,

Side Force at the Foot.

Rearward Force at the Foot.

Sideways Force at the Knee.

and, for the arm,

Side Force at the Hand (positive outwards)

Rearward Force at the Hand.

The helmet lift and side forces were measured on the bracket that supported it from the seat structure. The wearer's head was not in contact with the outer shell of the helmet.

Figure 3 gives a view of the seat in the tunnel during a test. Figures 4 through 8 constitute a pictorial record of the limb force measurement equipment, the helmet installation, and other details of the test set-up.

ACES-II Ejection Seat Alterations

A design review of the F-105 ejection seat modifications for wind tunnel testing concluded that changes to the ACES-II seat should be held to a minimum of additional support structures. The following modifications were made to the ACES-II ejection seat:

1) The ejection handles were positioned to accept strain-gauged beams (Figure 7).

2) The feet were also supported on strain-gauged beams with streamlined support structures (Figure 6).

The seat was mounted in the tunnel in such a manner that the angle made by the seat rails with the vertical was 13° for the datum or zero pitch attitude. This is the normal wind entry angle for most USAF ejection seats.

Standard Test Procedure

We assumed that all aerodynamic forces are proportional to the tunnel dynamic pressure. Typically

$$\text{Force} = (\text{coefficient}) \times (\text{area}) \times (q)$$

Figure 3. A Subject in the ACES II Seat at -15° Yaw, -15° Pitch.

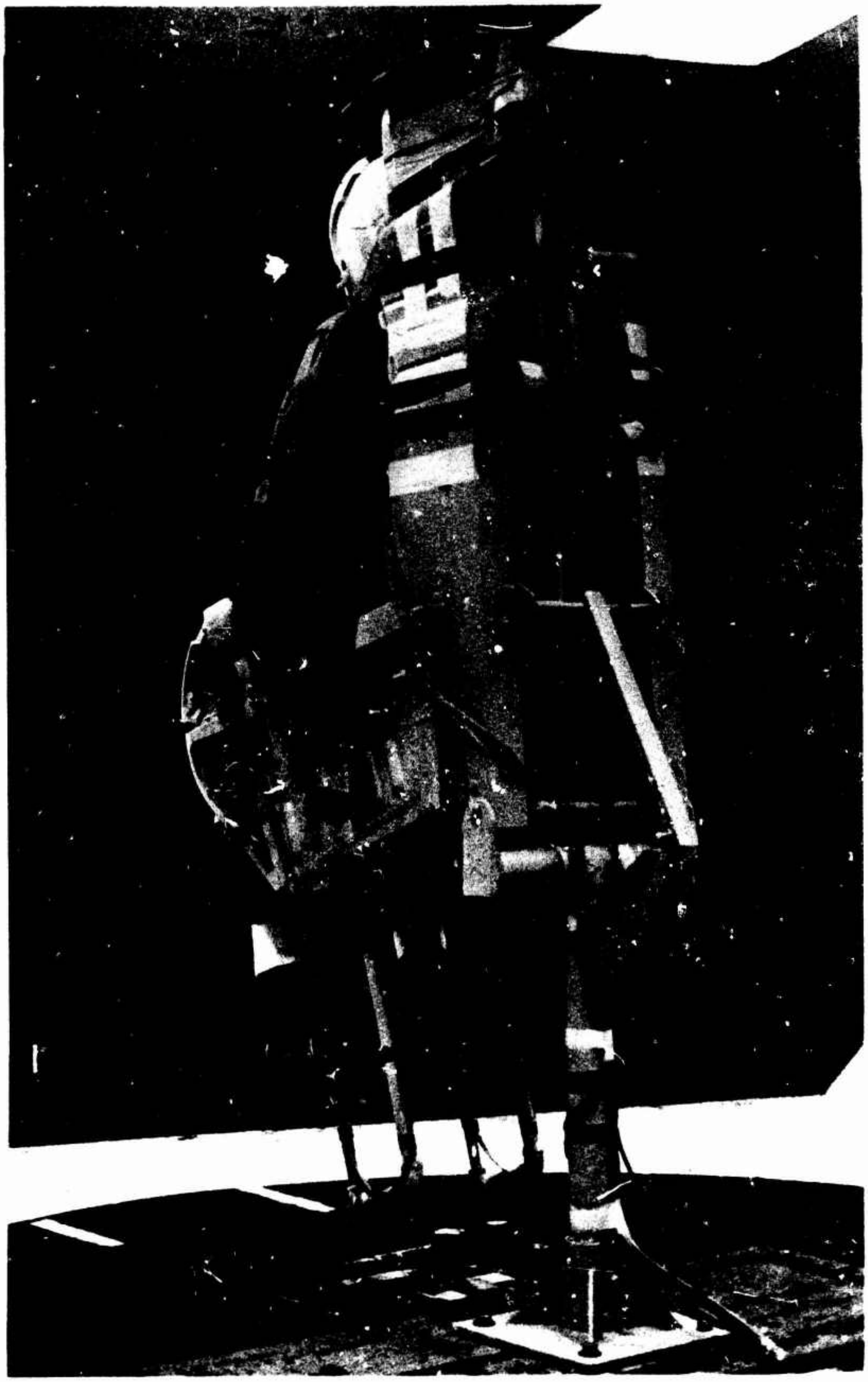


Figure 4. Rear View of the ACES II Seat and the Mounting Stand Built to Support it in the Tunnel. Pitch Angle is Controlled by the Inclined Strut at the Rear.

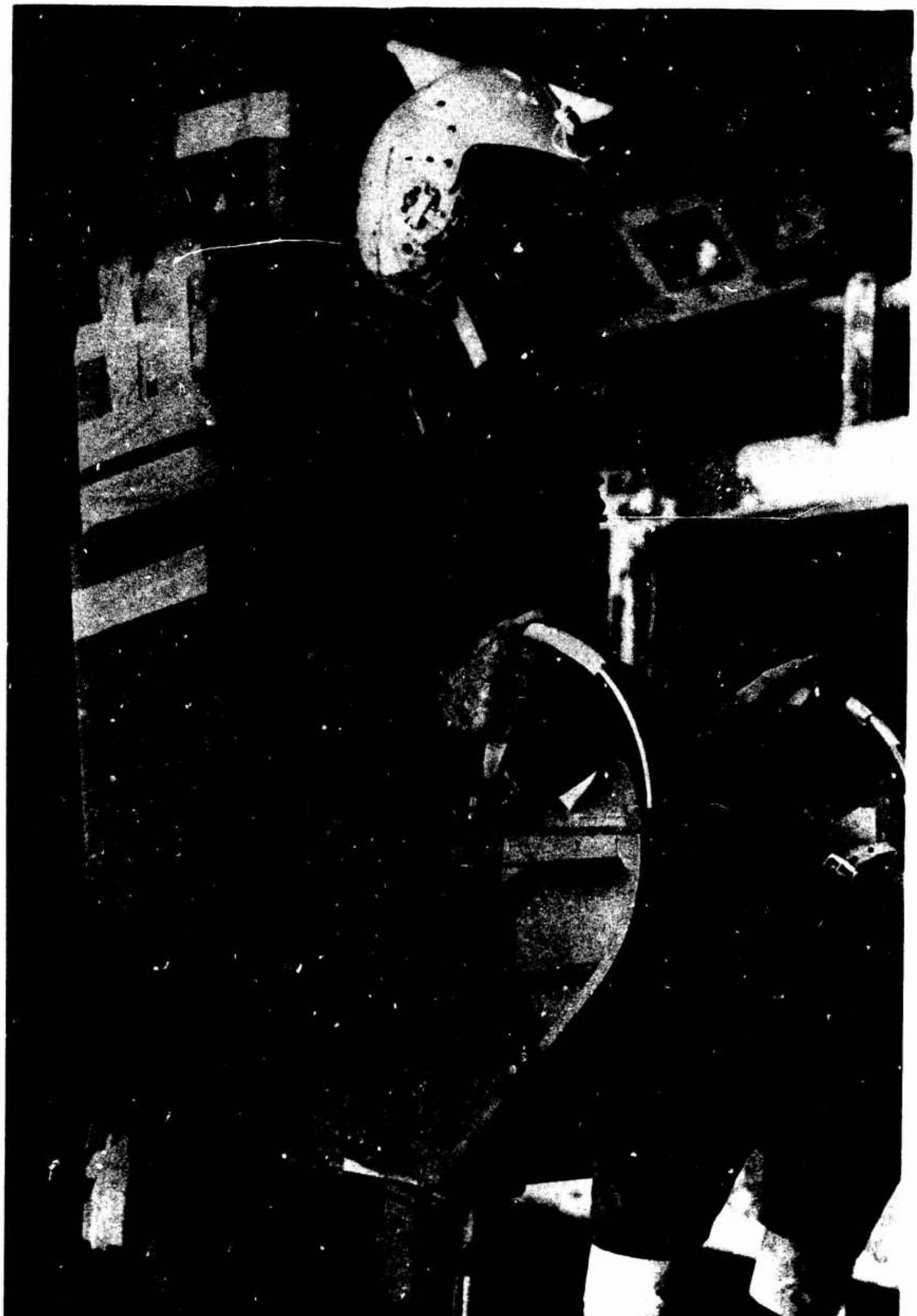


Figure 5. The ACES-II Side Arm Control Handles were Mounted on Strain-Gauged Cantilever Beams which Permit "In-Out" and "Forward-Back" Forces to be Measured.

Figure 6. ACES-II Foot Force ("Forward-Back" and "In-Out") was Measured on the Vertical Beams Supporting the Stirrups to which the Subject's Feet are Strapped.

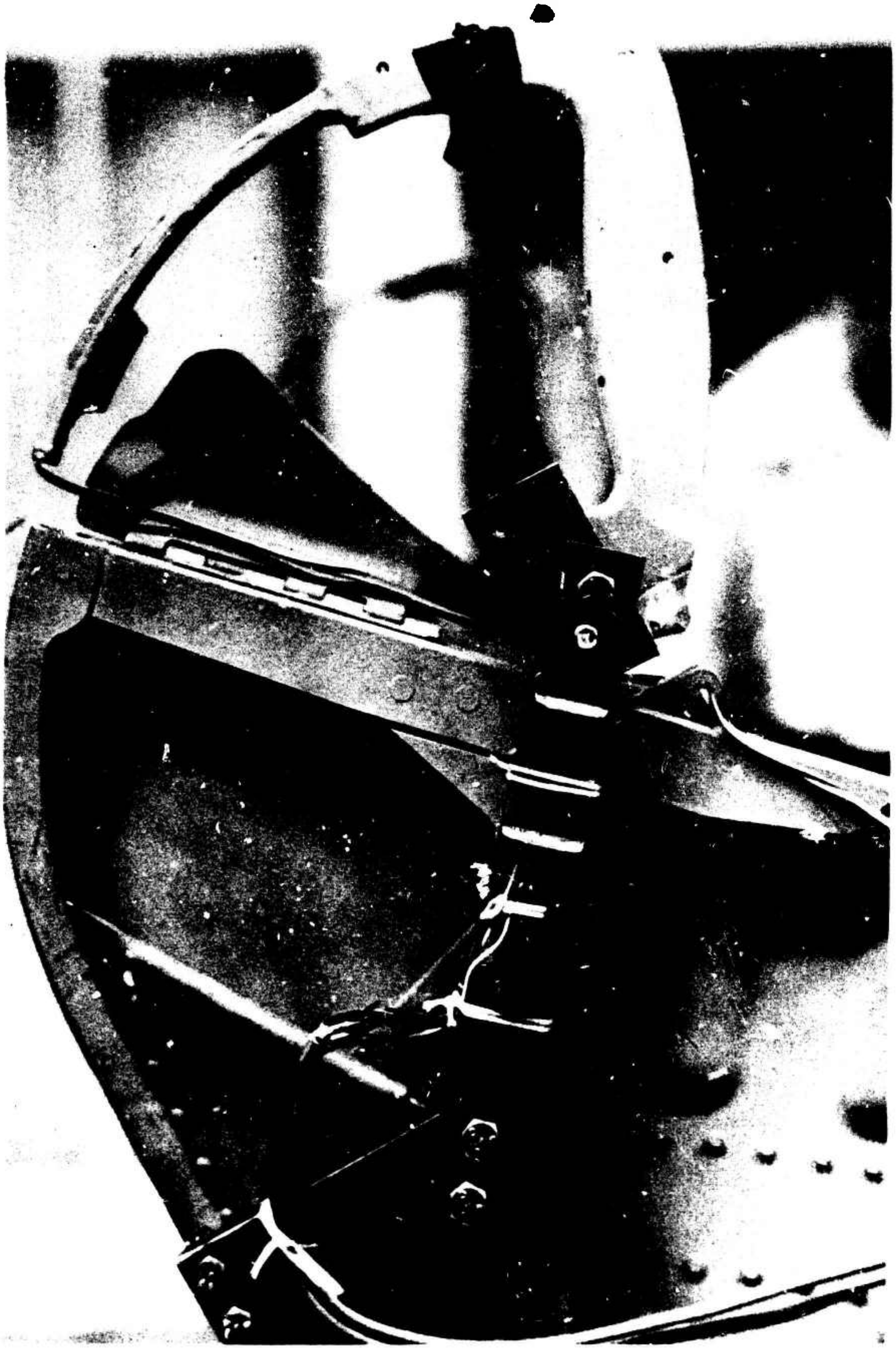


Figure 7. Detail of the ACES-II Side Control Force Measuring Beam.

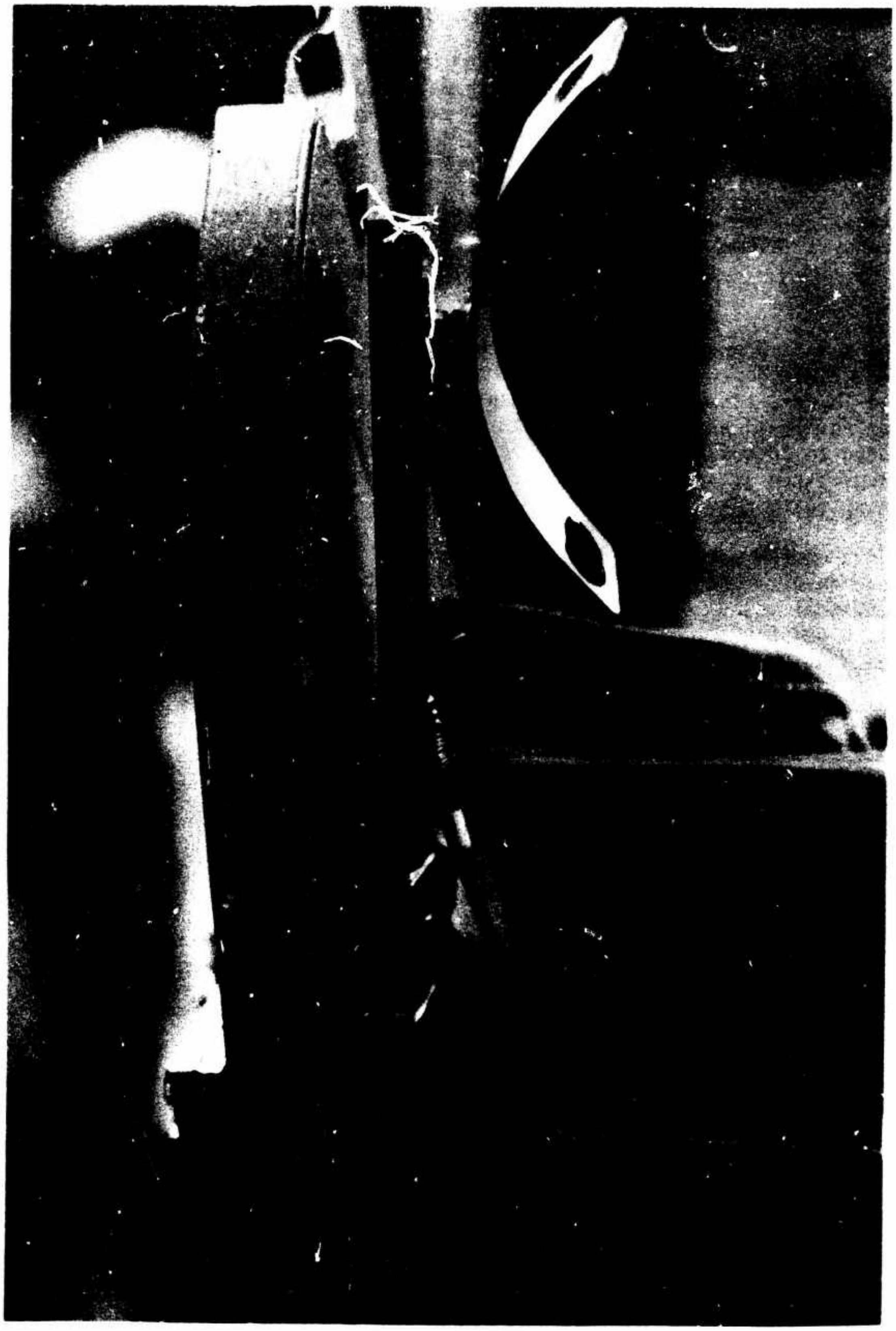


Figure 8. The Right Knee "In-Out" Force Measuring Beam on the ACES II Seat.

Since the significant area for a forearm or knee is hard to determine, the product (coefficient) x (area) is amalgamated into a single term (K), having the dimensions of area. Then,

$$\text{Force} = K_{area} \times q$$

Similarly, a moment, being the product of a force and a distance, may be represented by a volume

$$\text{Moment} = K_{volume} \times q$$

In the standard procedure, the particular test configuration is set up and remains fixed during the run. The tunnel is started and brought up to $q = 20\ lb/ft^2$. The experimental quantities (tunnel balance data, strain gauges) are read and recorded by the automatic system; the tunnel q is then advanced to 30 and 40 lb/ft^2 and dropped back to 30 and 20 lb/ft^2 with the readings taken at each pressure level; then, shut-down and preparation for the next test.

The data on IBM cards goes to the University's IBM 1620 computer. The tunnel balance data is entered in a program provided by the University to apply the conventional tunnel corrections and prints out force areas and moment volumes for each value of q. Printout comes in two versions; one with respect to tunnel axes of reference and another with the data transferred to body axes.

The dislodgement force data was treated similarly by a program prepared by Payne, Inc., which inserted the calibration for each gauge and printed out the forces for each value of the tunnel pressure q, then plotted the values against q, then by a least mean squares fit, found the best value for K for each case.

RESULTS AND DISCUSSION

The Test Data

The output from the IBM data processing is given in the following tables:

Table 1. Limb Dislodgement Forces

Table 2. Helmet Forces

Table 3. Seat Forces and Moments with Human Occupants

Table 4. Seat Forces and Moments with 5% Dummy

Table 5. Seat Forces and Moments with 95% Dummy

Table 6. Average Force Areas and Moment Volumes for Human Subjects

Seat forces and moments are referred to body axes through the normal CG. Data for displaced CG positions are derived from Table 5.

Limb Dislodgement Forces

Data from Table 1 is plotted in Figures 9 to 15.

Forces on the Hands

At 0° yaw and 30° pitch, the resultant hand forces are only 0.15 ft^2. This is less than half those for small angles of pitch (reference 1). At 60° pitch, the hand forces are practically zero (Figure 9). The resultant hand force gradually increases as yaw is increased.

The outward components of force for 30° to 60° pitch are negligibly small at zero yaw, developing finite values across the body with yaw up to 30° (Figure 10).

The rearward force is about the same for both hands, decreasing from 0.1 ft^2 at 30° yaw to zero at 60° yaw, as shown in Figure 11.

Large angles of pitch are clearly not a matter of concern in the development of hand forces.

Forces on the Legs

Outwards force at the knee is not measurably affected by the pitch angle with zero yaw, remaining at 0.15 ft^2 in the present series as in those of Reference 1. The asymmetrical effect of yaw is reduced progressively with pitch, the

Table 1. Average Limb Dislodgement Forces For the Aces II Seat at High Angles of Attack

Yaw Angle ψ	Pitch Angle α	8 Right Foot Back	5 Left Foot Back	7 Right Foot Out	6 Left Foot Out	9 Right Knee Out	10 Left Knee Out	3 Right Arm Out	2 Left Arm Out	4 Right Arm Back	1 Left Arm Back	Right Foot Resultant	Left Foot Resultant	Right Arm Resultant	Left Arm Resultant
0	30	0.1	0.09	0.05	0.02	0.11	0.10	0.02	0.01	0.11	0.14	0.11	0.09	0.11	0.14
0	45	0.01	0.0	0.01	0.0	0.14	0.09	0.01	0.0	0.03	0.05	0.01	0.0	0.03	0.05
0	60	-0.04	-0.06	-0.01	-0.01	0.17	0.14	0.0	-0.01	0.01	-0.02	0.04	0.06	0.01	0.02
-15	30	0.05	0.08	-0.03	0.19	0.01	0.26	0.01	0.09	0.11	-0.11	0.06	0.21	0.11	0.14
-15	45	-0.04	-0.02	-0.01	0.19	0.03	0.20	-0.04	0.0	0.1	0.04	0.04	0.19	0.11	0.04
-15	60	-0.05	-0.06	-0.03	0.12	0.03	0.13	-0.05	0.0	-0.02	0.01	0.06	0.13	0.05	0.01
-30	30	0.07	0.04	-0.11	0.37	-0.08	0.41	-0.07	0.14	0.09	0.12	0.13	0.37	0.11	0.18
-30	45	-0.01	-0.03	-0.12	0.29	-0.07	0.29	-0.08	0.03	0.0	0.02	0.12	0.29	0.08	0.04
-30	60	-0.6	-0.11	-0.10	0.22	-0.05	0.23	-0.11	0.0	-0.02	-0.02	0.12	0.25	0.11	0.02

Table 2. Helmet Forces for ACES-II Ejection Seat

		Gauge Numbers							Helmet Loss Preventor		
Yaw Angle ψ	Pitch Angle α	(11)	(12)	(13)	(14)	Side Force Area (12-11)	Lift Force Area (14-13)	Resultant	Side Force Area	Lift Force Area	Resultant
0	30	BD	BD	0.4	0.6	BD	0.2	--			
0	45	0.03	0.05	0.13	0.26	0.02	0.13	0.13			
0	60	-0.03	-0.03	0.04	0.07	0.0	0.03	0.05			
-15	30	-0.13	-0.18	0.40	0.71	-0.05	0.31	0.31			
-15	45	-0.15	-0.21	0.40	0.72	-0.06	0.32	0.33			
-15	60	-0.09	-0.12	0.26	0.48	-0.03	0.22	0.22			
-30	30	-1.27	-1.68	0.44	0.81	-0.41	0.37	0.55			
-30	45	-1.06	-1.47	0.36	0.66	-0.41	0.30	0.51			
-30	60	-0.49	[illegible]	0.23	0.40	-0.21	0.17	0.27			
0	-15								0.05	0.05	0.07
0	0								0.03	0.18	0.18
0	15								0.06	0.24	0.25
-15	-15								-0.15	0.01	0.15
-15	0								-0.22	0.14	0.26
-15	15								-0.06	0.28	0.29
-30	-15								-0.55	0.11	0.56
-30	0								-0.40	0.18	0.44
-30	15								-0.30	0.28	0.41

BD - Bad Data

Table 3. Seat Forces and Moments With Human Occupants.

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO 013 684 — BODY AXES 10/25/74
00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	000.0	0001.9	004.61	-0001.8	-0000.7	-00001.0	0000.4	00.947		020.00
030.0	000.0	0001.9	004.47	-0001.8	-0000.7	-00001.0	0000.4	00.947		030.00
030.0	-000.0	0001.9	004.46	-0001.9	-0000.7	-00001.1	0000.4	01.000		040.00
030.0	-000.0	0001.9	004.35	-0001.7	-0000.6	-00000.9	0000.4	00.894		050.00
030.0	-000.0	0001.9	004.42	-0001.7	-0000.7	-00001.0	0000.4	00.894		040.00
030.0	-000.0	0001.9	004.46	-0001.7	-0000.7	-00001.0	0000.4	00.894		030.00
030.0	-000.0	0001.9	004.64	-0001.7	-0000.6	-00000.9	0000.4	00.894		020.00

RUN NO TEST NO 014 684 — BODY AXES 10/25/74
00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	-015.0	0002.1	004.65	-0001.6	-0001.4	00001.1	-0001.9	00.761		020.00
030.0	-015.0	0002.2	004.73	-0001.5	-0001.7	00001.3	-0002.0	00.681		030.00
030.0	-015.0	0002.1	004.69	-0001.4	-0001.7	00001.3	-0002.0	00.666		040.00
030.0	-015.0	0002.2	004.71	-0001.5	-0001.7	00001.4	-0002.0	00.681		050.00
030.0	-015.0	0002.1	004.70	-0001.4	-0001.6	00001.4	-0001.9	00.666		040.00
030.0	-015.0	0002.1	004.77	-0001.4	-0001.6	00001.2	-0001.9	00.666		030.00
030.0	-015.0	0002.1	004.74	-0001.5	-0001.6	00001.3	-0001.9	00.714		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND

WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO
015 684

BODY AXES 10/25/74
00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	-030.0	0002.3	004.43	-0001.5	-0002.3	00002.3	-0005.2	00.652		020.00
030.0	-030.0	0002.3	004.39	-0001.3	-0002.5	00001.9	-0005.2	00.565		030.00
030.0	-030.0	0002.2	004.45	-0001.4	-0002.4	00002.1	-0005.3	00.636		040.00
030.0	-030.0	0002.2	004.39	-0001.4	-0002.4	00002.1	-0005.4	00.636		050.00
030.0	-030.0	0002.3	004.52	-0001.5	-0002.5	00001.9	-0005.3	00.652		040.00
030.0	-030.0	0002.1	004.25	-0001.0	-0002.4	00001.9	-0005.0	00.476		030.00
030.0	-030.0	0002.3	004.43	-0001.1	-0002.5	00001.8	-0005.2	00.478		020.00

RUN NO TEST NO
016 684

BODY AXES 10/25/74
00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-000.0	0003.3	003.04	-0001.8	-0000.8	-00000.7	0000.3	00.545		020.00
045.0	000.0	0003.2	002.79	-0001.4	-0000.9	-00000.6	0000.3	00.437		030.00
045.0	000.0	0003.4	002.80	-0001.5	-0001.0	-00000.7	0000.3	00.441		040.00
045.0	000.0	0003.4	002.85	-0001.5	-0000.8	-00000.7	0000.3	00.441		030.00
045.0	000.0	0003.3	002.92	-0001.5	-0000.8	-00000.7	0000.3	00.454		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO BODY AXES 10/25/74
017 684 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-015.0	0003.8	002.90	-0001.0	-0001.2	00000.7	-0001.9	00.263		020.00
045.0	-015.0	0003.7	002.81	-0001.0	-0001.6	00000.7	-0001.7	00.270		030.00
045.0	-015.0	0003.6	002.91	-0001.1	-0001.6	00000.8	-0001.8	00.305		040.00
045.0	-015.0	0003.8	002.91	-0001.0	-0001.6	00000.8	-0001.8	00.263		030.00
045.0	-015.0	0003.8	002.96	-0001.0	-0001.6	00000.8	-0001.9	00.263		020.00

RUN NO TEST NO BODY AXES 10/25/74
018 684 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-030.0	0003.8	003.05	-0000.8	-0001.9	00002.4	-0004.7	00.210		020.00
045.0	-030.0	0003.6	003.04	-0000.8	-0002.1	00002.3	-0004.8	00.222		030.00
045.0	-030.0	0003.6	003.13	-0000.7	-0002.2	00002.2	-0004.8	00.194		040.00
045.0	-030.0	0003.6	003.06	-0000.7	-0002.2	00002.0	-0004.8	00.194		030.00
045.0	-030.0	0003.7	003.17	-0000.7	-0002.3	00002.3	-0004.9	00.189		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO 019 TEST NO 684 — BODY AXES — 10/25/74
00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-000.0	0004.1	002.12	-0000.4	-0000.7	-00000.8	0000.4	00.097		020.00
060.0	-000.0	0004.0	002.06	-0000.3	-0000.9	-00000.9	0000.4	00.075		030.00
060.0	-000.0	0004.0	002.08	-0000.3	-0000.9	-00000.8	0000.3	00.075		040.00
060.0	-000.0	0004.0	002.06	-0000.3	-0000.9	-00000.7	0000.3	00.075		030.00
060.0	000.0	0004.1	002.12	-0000.3	-0000.7	-00000.8	0000.3	00.073		020.00

RUN NO 020 TEST NO 684 — BODY AXES — 10/25/74
00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-015.0	0004.3	001.79	-0000.4	-0001.3	00000.5	-0001.2	00.093		020.00
060.0	-015.0	0004.2	001.64	-0000.2	-0001.3	00000.4	-0001.2	00.047		030.00
060.0	-015.0	0004.2	001.94	-0000.4	-0001.3	00000.5	-0001.1	00.095		040.00
060.0	-015.0	0004.2	001.75	-0000.2	-0001.4	00000.3	-0001.1	00.047		030.00
060.0	-015.0	0004.2	001.76	-0000.4	-0001.2	00000.5	-0001.2	00.095		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO — BODY AXES — 10/25/74

021 684 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-030.0	0004.3	001.70	-0000.3	-0001.8	00002.4	-0004.0	00.069		020.00
060.0	-030.0	0004.3	001.69	-0000.2	-0001.9	00002.3	-0004.0	00.046		030.00
060.0	-030.0	0004.3	001.80	-0000.3	-0001.8	00002.4	-0004.2	00.069		040.00
060.0	-030.0	0004.3	001.80	-0000.1	-0002.0	00002.5	-0004.2	00.023		030.00
060.0	-030.0	0004.3	001.81	-0000.0	-0002.1	00002.4	-0004.2	00.000		020.00

RUN NO TEST NO — BODY AXES — 10/25/74

022 684 — 00 50 03 02 44 00 00 00

AA	AY	L'	D	PM	YM	RM	SF	C CP	L D	Q
030.0	000.0	0002.0	004.41	-0002.2	-0000.6	-00001.3	0000.4	01.100		020.00
030.0	-000.0	0002.0	004.31	-0002.0	-0000.7	-00001.3	0000.4	01.000		030.00
030.0	-000.0	0002.0	004.28	-0002.1	-0000.8	-00001.2	0000.3	01.050		040.00
030.0	-000.0	0002.0	004.30	-0002.0	-0000.7	-00001.3	0000.4	01.000		030.00
030.0	-000.0	0002.1	004.43	-0002.2	-0000.7	-00001.1	0000.3	01.047		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO — 023 684 — BODY AXES — 00 50 03 02 44 00 00 00 — 10/25/74

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	-015.0	0002.1	004.49	-0001.8	-0001.5	00001.0	-0001.7	00.857		020.00
030.0	-015.0	0002.1	004.44	-0001.7	-0001.6	00001.0	-0001.7	00.809		030.00
030.0	-015.0	0002.0	004.54	-0001.6	-0001.7	00001.3	-0001.6	00.800		040.00
030.0	-015.0	0002.2	004.53	-0001.7	-0001.7	00001.3	-0001.9	00.772		030.00
030.0	-015.0	0002.2	004.51	-0001.7	-0001.5	00001.4	-0001.9	00.772		020.00

RUN NO TEST NO — 024 684 — BODY AXES — 00 50 03 02 44 00 00 00 — 10/25/74

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	-030.0	0002.2	003.99	-0001.5	-0002.3	00002.6	-0005.0	00.681		020.00
030.0	-030.0	0002.2	004.01	-0001.5	-0002.4	00002.5	-0005.1	00.681		030.00
030.0	-030.0	0002.2	004.17	-0001.5	-0002.5	00002.5	-0005.2	00.681		040.00
030.0	-030.0	0002.1	004.28	-0001.5	-0002.6	00002.4	-0005.2	00.714		030.00
030.0	-030.0	0002.1	004.28	-0001.5	-0002.6	00002.3	-0005.2	00.714		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO	TEST NO	BODY AXES	10/25/74
025	684	00 50 03 02 44 00 00 00	

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	000.0	0003.0	003.12	-0001.9	-0000.9	-00000.9	0000.3	00.633		020.00
045.0	-000.0	0003.2	002.67	-0001.5	-0000.6	-00001.1	0000.5	00.468		030.00
045.0	-000.0	0003.2	002.65	-0001.5	-0000.8	-00001.1	0000.5	00.468		040.00
045.0	-000.0	0003.2	002.63	-0001.4	-0000.7	-00001.0	0000.5	00.437		030.00
045.0	-000.0	0003.2	002.67	-0001.5	-0000.6	-00000.9	0000.5	00.468		020.00

RUN NO	TEST NO	BODY AXES	10/25/74
026	684	00 50 03 02 44 00 00 00	

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-015.0	0003.7	002.95	-0000.8	-0001.3	00000.6	-0001.6	00.216		020.00
045.0	-015.0	0003.5	002.89	-0000.9	-0001.3	00000.5	-0001.5	00.257		030.00
045.0	-015.0	0003.5	002.96	-0000.9	-0001.4	00000.7	-0001.6	00.257		040.00
045.0	-015.0	0003.5	002.94	-0000.8	-0001.4	00000.7	-0001.6	00.228		030.00
045.0	-015.0	0003.6	003.00	-0000.9	-0001.3	00000.7	-0001.7	00.250		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO 027 684 — BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-030.0	0003.6	002.93	-0000.7	-0001.9	00002.3	-0004.4	00.194		020.00
045.0	-030.0	0003.5	002.90	-0000.6	-0002.0	00002.4	-0004.4	00.171		030.00
045.0	-030.0	0003.4	003.01	-0000.6	-0002.0	00002.5	-0004.5	00.176		040.00
045.0	-030.0	0003.6	002.87	-0000.5	-0002.2	00002.4	-0004.5	00.138		030.00
045.0	-030.0	0003.7	002.97	-0000.5	-0002.1	00002.3	-0004.4	00.135		020.00

RUN NO TEST NO 028 684 — BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	000.0	0004.0	001.95	-0000.7	-0000.6	-00001.0	0000.5	00.175		020.00
060.0	000.0	0003.8	001.82	-0000.5	-0000.8	-00000.9	0000.5	00.131		030.00
060.0	000.0	0003.8	001.85	-0000.4	-0000.8	-00000.9	0000.5	00.105		040.00
060.0	-000.0	0003.7	001.93	-0000.5	-0000.8	-00000.9	0000.5	00.135		030.00
060.0	000.0	0003.9	002.01	-0000.6	-0000.5	-00000.7	0000.4	00.153		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO
029 684

BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-015.0	0004.2	001.71	-0000.4	-0000.9	00000.1	-0000.8	00.095		020.00
060.0	-015.0	0004.1	001.56	-0000.3	-0001.0	00000.2	-0000.9	00.073		030.00
060.0	-015.0	0004.0	001.88	-0000.5	-0001.0	00000.1	-0000.8	00.125		040.00
060.0	-015.0	0004.2	001.62	-0000.4	-0001.0	00000.1	-0000.9	00.095		030.00
060.0	-015.0	0004.1	001.78	-0000.6	-0000.9	00000.3	-0000.9	00.146		020.00

RUN NO TEST NO
030 684

BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-030.0	0004.4	001.29	-0000.0	-0001.7	00002.2	-0003.8	00.000		020.00
060.0	-030.0	0004.3	001.34	-0000.0	-0001.7	00002.4	-0003.8	00.000		030.00
060.0	-030.0	0004.3	001.34	-0000.0	-0001.7	00002.3	-0003.8	00.000		040.00
060.0	-030.0	0004.4	001.37	-0000.0	-0001.8	00002.5	-0003.8	00.000		030.00
060.0	-030.0	0004.3	001.33	-0000.0	-0001.8	00002.1	-0003.7	00.000		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO BODY AXES 10/25/74
031 684 00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	000.0	0002.0	004.33	-0002.1	-0000.5	-00001.2	0000.5	01.050		020.00
030.0	000.0	0002.1	004.20	-0001.9	-0000.7	-00001.4	0000.5	00.904		030.00
030.0	-000.0	0002.2	004.13	-0001.9	-0000.7	-00001.4	0000.5	00.863		040.00
030.0	-000.0	0002.1	004.15	-0001.9	-0000.7	-00001.3	0000.5	00.904		030.00
030.0	-000.0	0002.1	004.31	-0001.9	-0000.5	-00001.1	0000.4	00.904		020.00

RUN NO TEST NO BODY AXES 10/25/74
032 684 00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	-015.0	0002.3	004.64	-0002.0	-0001.5	00001.5	-0002.2	00.869		020.00
030.0	-015.0	0002.1	004.27	-0001.6	-0001.6	00001.1	-0002.0	00.761		030.00
030.0	015.0	0002.1	004.37	-0001.6	-0001.7	00001.1	-0002.0	00.761		040.00
030.0	-015.0	0002.1	004.27	-0001.6	-0001.6	00001.2	-0002.0	00.761		030.00
030.0	-015.0	0002.2	004.37	-0001.6	-0001.5	00001.3	-0002.0	00.818		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO
033 684

BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	-030.0	0002.2	004.02	-0001.5	-0002.2	00002.3	-0005.1	00.681		020.00
030.0	-030.0	0002.1	004.09	-0001.3	-0002.2	00002.1	-0005.1	00.619		030.00
030.0	-030.0	0002.2	004.17	-0001.4	-0002.3	00002.2	-0005.2	00.636		040.00
030.0	-030.0	0002.2	004.21	-0001.4	-0002.2	00002.1	-0005.2	00.636		030.00
030.0	-030.0	0002.2	004.25	-0001.4	-0002.5	00002.1	-0005.3	00.636		020.00

RUN NO TEST NO
034 684

BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
-045.0	000.0	-0002.6	003.20	0001.4	0000.1	-00001.1	0000.3	00.538		020.00
045.0	000.0	0003.2	002.65	-0001.5	-0000.9	-00000.9	0000.4	00.468		030.00
045.0	000.0	0003.2	002.64	-0001.5	-0000.9	-00000.9	0000.4	00.468		040.00
045.0	000.0	0003.2	002.65	-0001.5	-0000.8	-00001.0	0000.5	00.468		030.00
045.0	000.0	0003.3	002.79	-0001.6	-0000.8	-00000.8	0000.4	00.484		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO
035 684

BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-015.0	0003.5	002.79	-0001.2	-0001.2	00000.8	-0001.8	00.342		020.00
045.0	-015.0	0003.4	002.70	-0001.1	-0001.2	00000.5	-0001.7	00.323		030.00
045.0	-015.0	0003.4	002.79	-0001.2	-0001.4	00000.6	-0001.7	00.352		040.00
045.0	-015.0	0003.4	002.86	-0001.2	-0001.4	00000.7	-0001.7	00.352		030.00
045.0	-015.0	0003.5	002.90	-0001.3	-0001.4	00000.7	-0001.7	00.371		020.00

RUN NO TEST NO
03[illegible] 684

BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-030.0	0003.6	002.86	-0000.7	-0001.8	00002.3	-0004.6	00.194		020.00
045.0	-030.0	0003.5	002.78	-0000.6	-0001.9	00002.3	-0004.5	00.171		030.00
045.0	-030.0	0003.4	003.00	-0000.7	-0002.0	00002.3	-0004.5	00.205		040.00
045.0	-030.0	0003.5	002.93	-0000.6	-0002.1	00002.2	-0004.5	00.171		030.00
045.0	-030.0	0003.6	002.91	-0000.6	-0002.2	00002.2	-0004.5	00.166		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO — BODY AXES — 10/25/74

037 684 — 00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	000.0	0003.9	001.93	-0000.7	-0000.7	-00000.6	0000.4	00.179		020.00
060.0	000.0	0003.9	001.89	-0000.5	-0000.9	-00000.9	0000.5	00.128		030.00
060.0	000.0	0003.8	001.86	-0000.5	-0000.9	-00000.7	0000.4	00.131		040.00
060.0	000.0	0003.8	001.86	-0000.5	-0000.9	-00000.7	0000.4	00.131		030.00
060.0	000.0	0003.9	001.90	-0000.7	-0000.7	-00000.6	0000.3	00.179		020.00

RUN NO TEST NO — BODY AXES — 10/25/74

038 684 — 00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-015.0	0004.0	001.71	-0000.6	-0001.0	00000.1	-0000.7	00.150		020.00
060.0	-015.0	0004.0	001.60	-0000.5	-0001.0	-00000.0	-0000.6	00.125		030.00
060.0	-015.0	0003.9	001.79	-0000.6	-0001.1	00000.1	-0000.6	00.153		040.00
060.0	-015.0	0004.0	001.71	-0000.5	-0001.0	00000.1	-0000.6	00.125		030.00
060.0	-015.0	0004.0	001.73	-0000.7	-0000.9	00000.3	-0000.8	00.175		020.00

Table 3. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO
039 684

BODY AXES 10/25/74
00 50 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-030.0	0004.1	001.46	-0000.5	-0001.5	00002.0	-0003.6	00.121		020.00
060.0	-030.0	0004.1	001.34	-0000.4	-0001.5	00002.2	-0003.6	00.097		030.00
060.0	-030.0	0004.0	001.41	-0000.5	-0001.5	00002.1	-0003.6	00.125		040.00
060.0	-030.0	0004.0	001.48	-0000.5	-0001.5	00002.2	-0003.6	00.125		030.00
060.0	-030.0	0004.0	001.48	-0000.5	-0001.7	00002.2	-0003.6	00.125		020.00

Table 4. Seat Forces and Moments With 5% Dummy.

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO
3 684

BODY AXES 10/25/74
0* 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
000.0	000.0	-0001.9	007.18	-0000.3	-0000.3	-00000.0	0000.5	-00.157		030.00
000.0	-015.0	-0001.8	007.01	-0000.4	-0001.4	00001.4	-0002.4	-00.222		030.00
000.0	-030.0	-0001.6	006.56	-0001.6	-0002.8	00002.7	-0005.5	-01.000		030.00
000.0	-060.0	-0000.9	003.02	-0001.8	-0002.9	00002.4	-0009.8	-02.000		030.00
000.0	-090.0	-0000.6	000.20	-0001.4	-0001.2	00003.8	-0009.7	-02.333		030.00
000.0	-120.0	0000.5	-002.95	-0001.3	0000.3	00003.6	-0008.7	02.600		030.00
000.0	-150.0	000[illegible].6	-006.44	0000.6	-0000.4	00001.6	-0004.4	-01.000		030.00
000.0	-180.0	0001.5	-005.27	-0000.7	0000.4	00000.0	-0000.1	00.466		030.00

Bad Data - Dummy Not
Properly Installed in Seat

Table 4. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO 4 684 — BODY AXES 10/25/74
00 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
000.0	-000.0	-0001.6	006.30	-0002.3	-0000.4	-00000.1	0000.6	-01.437		050.00
000.0	-015.0	-0001.4	006.29	-0002.0	-0001.7	00001.4	-0001.9	-01.428		050.00
000.0	-030.0	-0001.4	005.92	-0002.6	-0003.0	00003.1	-0005.0	-01.857		050.00
000.0	-060.0	-0001.1	002.92	-0002.3	-0003.1	00003.3	-0009.7	-02.090		050.00
000.0	-090.0	-0000.8	000.40	-0000.9	-0001.1	00003.6	-0009.6	-01.125		050.00
000.0	-120.0	0000.3	-002.84	-0001.3	0000.3	00003.6	-0008.7	04.333		050.00
000.0	-150.0	0000.5	-006.59	0000.7	-0000.6	00001.1	-0004.1	-01.400		050.00
000.0	-180.0	0001.4	-005.46	-0000.6	0000.4	-00000.2	-0000.1	00.428		050.00

RUN NO TEST NO 5 684 — BODY AXES 10/25/74
0 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
-015.0	000.0	-0002.8	006.06	-0002.0	-0000.5	00000.3	0000.3	-00.714		030.00
-015.0	-015.0	-0002.5	005.95	-0001.5	-0002.1	00001.8	-0002.1	-00.600		030.00
-015.0	-030.0	-0002.4	005.68	-0002.2	-0003.0	00001.9	-0005.3	-00.916		030.00
-015.0	-060.0	-0001.6	002.54	-0001.7	-0003.1	00002.3	-0009.6	-01.062		030.00
-015.0	-090.0	-0000.7	000.23	-0001.1	-0001.2	00003.8	-0009.7	-01.571		030.00
-015.0	-120.0	0000.4	-003.47	-0000.0	-0000.4	00004.7	-0008.6	00.000		030.00
-015.0	-150.0	0001.6	-006.57	0001.4	-0000.6	00001.7	-0004.5	-00.875		030.00
-015.0	-180.0	0001.6	-005.83	0000.8	0000.5	00000.1	-0000.4	-00.500		030.00

Table 4. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO — 6 684 — BODY AXES — 0* 5 03 02 44 00 00 00 — 10/25/74

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
-015.0	000.0	-0002.8	006.18	-0002.1	-0000.4	-00000.1	0000.1	-00.750		050.00
-015.0	-015.0	-0002.5	006.25	-0001.7	-0002.3	00001.7	-0002.1	-00.680		050.00
-015.0	-030.0	-0002.4	006.03	-0002.6	-0003.0	00002.0	-0005.3	-01.166		050.00
-015.0	-060.0	-0001.7	003.02	-0002.4	-0002.7	00002.5	-0009.8	-01.411		050.00
-015.0	-090.0	-0000.8	000.30	-0000.8	-0001.2	00003.6	-0009.7	-01.000		050.00
-015.0	-120.0	0000.4	-003.73	0000.4	-0000.6	00004.4	-0008.6	-01.000		050.00
-015.0	-150.0	0001.6	-006.56	0001.6	-0000.7	00001.6	-0004.2	-01.000		050.00
-015.0	-180.0	0001.4	-005.94	0001.2	0000.5	-00000.4	-0000.2	-00.857		050.00

RUN NO TEST NO — 7 684 — BODY AXES — 0* 5 03 02 44 00 00 00 — 10/25/74

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
015.0	-180.0	0001.1	-005.17	-0001.9	0000.1	-00000.1	0000.2	01.727		030.00
015.0	-150.0	0000.2	-005.83	-0000.0	-0000.2	00000.6	-0004.4	00.000		030.00
015.0	-120.0	-0000.0	-002.45	-0000.8	0000.7	00002.5	-0008.3			030.00
015.0	-090.0	-0000.6	000.16	-0001.2	-0000.9	00004.1	-0009.7	-02.000		030.00
015.0	-060.0	-0000.2	002.95	-0003.3	-0002.8	00003.9	-0009.2	-16.500		030.00
015.0	-030.0	0000.5	005.52	-0003.3	-0002.8	00003.0	-0005.1	06.600		030.00
015.0	-015.0	0000.2	006.19	-0002.5	-0001.9	00001.7	-0002.3	12.500		030.00
015.0	-000.0	0000.4	005.93	-0002.4	-0000.6	-00000.6	0001.0	06.000		030.00

Table 4. (continued)

UNIVERSITY OF MARYLAND

WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO BODY AXES 10/25/74

8 684 00 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
015.0	000.0	0000.3	006.09	-0002.4	-0000.5	-00000.7	0001.1	08.000		050.00
015.0	-015.0	0000.4	006.85	-0002.4	-0001.5	00001.3	-0002.5	06.000		050.00
015.0	-030.0	0000.6	006.08	-0002.7	-0002.2	00003.3	-0005.3	04.500		050.00
015.0	-030.0	0000.3	005.82	-0003.3	-0002.8	00002.8	-0005.0	11.000		050.00
015.0	-060.0	-0000.6	002.49	-0001.7	-0002.7	00003.3	-0008.7	-02.833		050.00
015.0	-090.0	-0000.9	000.14	0000.0	-0001.2	00002.6	-0008.8	00.000		050.00
015.0	-120.0	-0000.1	-002.71	-0000.9	0000.6	00002.3	-0008.6	-09.000		050.00
015.0	-150.0	0000.0	-006.02	0000.4	-0000.4	00000.1	-0004.3			050.00
015.0	-180.0	0001.0	-005.56	-0001.2	-0000.2	-00001.0	0000.6	01.200		050.00

RUN NO TEST NO BODY AXES 10/25/74

9 684 0* 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	-180.0	-0000.3	-005.17	-0001.5	-0000.4	-00000.6	0001.0	-04.333		030.00
030.0	-150.0	-0000.3	-005.35	-0000.3	0000.3	-00001.0	-0005.3	-01.000		030.00
030.0	-120.0	-0000.2	-002.02	-0000.6	0000.9	00001.6	-0008.4	-03.000		030.00
030.0	-090.0	-0000.8	-000.22	0000.1	-0000.9	00003.2	-0009.4	00.125		030.00
030.0	-060.0	0000.3	002.33	-0001.8	-0002.5	00004.7	-0009.4	06.000		030.00
030.0	-030.0	0002.1	004.73	-0002.9	-0002.5	00002.9	-0005.1	01.380		030.00
030.0	-015.0	0002.0	005.02	-0002.4	-0001.8	00001.2	-0002.3	01.200		030.00
030.0	-000.0	0002.1	004.39	-0002.3	-0000.7	-00000.9	0000.4	01.095		030.00

Table 4. (continued)

UNIVERSITY OF MARYLAND

WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO — BODY AXES 10/25/74

010 684 — 0* 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	000.0	0002.0	004.38	-0002.2	-0000.6	-00000.9	0000.6	01.100		050.00
030.0	-015.0	0001.8	004.75	-0001.8	-0001.6	00001.4	-0002.3	01.000		050.00
030.0	-030.0	0001.8	004.42	-0001.9	-0002.2	00003.2	-0005.1	01.055		050.00
030.0	-060.0	0000.3	002.28	-0001.1	-0002.4	00004.4	-0009.5	03.666		050.00
030.0	-090.0	-0001.1	000.07	0000.4	-0000.9	00003.1	-0009.6	00.363		050.00
030.0	-120.0	-0000.5	-002.16	0000.0	0000.8	00001.3	-0008.4	00.000		050.00
030.0	-150.0	-0000.5	-005.32	0000.4	0000.1	-00001.2	-0004.9	00.600		050.00
030.0	-180.0	-0000.3	-005.20	-0001.2	-0000.2	-00000.8	0000.9	-04.000		050.00

RUN NO TEST NO — BODY AXES 10/25/74

011 684 — 0* 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	-180.0	-0001.5	-003.93	-0000.8	-0000.8	-00000.2	0000.5	-00.533		030.00
045.0	-150.0	-0001.4	-003.94	0000.3	0000.4	-00001.7	-0005.5	00.214		030.00
045.0	-120.0	-0000.7	-001.26	0000.1	0000.6	00000.6	-0008.4	00.142		030.00
045.0	-090.0	-0000.9	-000.07	0000.0	-0001.1	00003.0	-0009.5	00.000		030.00
045.0	-060.0	0001.1	001.49	-0000.7	-0002.3	00004.7	-0009.1	00.636		030.00
045.0	-030.0	0003.3	003.25	-0001.3	-0002.0	00002.6	-0004.6	00.393		030.00
045.0	-015.0	0003.4	003.02	-0001.4	-0001.5	00000.7	-0001.7	00.411		030.00
045.0	000.0	0003.1	002.65	-0001.5	-0000.8	-00001.1	0000.5	00.483		030.00

Table 4. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO BODY AXES 10/25/74

012 684 0 5 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	-180.0	-0002.4	-002.09	-0000.4	-0000.6	-00000.1	0000.4	-00.166		030.00
060.0	-150.0	-0002.5	-001.76	0000.7	0000.4	-00001.8	-0006.1	00.280		030.00
060.0	-120.0	-0000.9	-000.53	0000.2	0000.2	00000.2	-0008.2	00.222		030.00
060.0	-090.0	-0000.6	-000.44	0000.1	-0001.0	00002.7	-0009.0	00.166		030.00
060.0	-060.0	0001.7	000.63	-0000.1	-0002.1	00005.0	-0009.1	00.058		030.00
060.0	-030.0	0003.9	001.55	-0000.3	-0001.6	00002.4	-0003.8	00.076		030.00
060.0	-015.0	0004.5	001.90	-0000.5	-0000.3	00001.6	-0002.0	00.111		030.00
060.0	-000.0	0003.7	001.78	-0000.4	-0000.8	-00000.8	0000.5	00.108		030.00

Table 5. Seat Forces and Moments With 95% Dummy.

UNIVERSITY OF MARYLAND

WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO 048 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
-015.0	-000.0	-0002.2	006.07	-0001.1	-0000.3	-00001.1	0000.5	-00.500		030.00
-015.0	-015.0	-0002.1	006.11	-0001.0	-0002.0	00000.6	-0001.3	-00.476		030.00
-015.0	-030.0	-0002.1	005.83	-0001.3	-0002.3	00001.0	-0004.8	-00.619		030.00

RUN NO TEST NO 059 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
-015.0	-060.0	-0001.6	003.05	-0001.2	-0002.4	00001.0	-0009.6	-00.750		030.00
-015.0	-090.0	-0000.7	-000.40	0000.2	-0000.4	00001.6	-0009.7	00.285		030.00
-015.0	-120.0	0000.8	-003.90	0000.6	0000.4	00002.2	-0008.5	-00.750		030.00
-015.0	-150.0	0001.6	-007.86	0002.2	-0000.3	00000.5	-0004.2	-01.375		030.00
-015.0	-180.0	0001.5	-005.90	0000.7	0000.0	-00000.9	0000.1	-00.466		030.00

RUN NO TEST NO 047 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
000.0	-000.0	-0001.3	006.32	-0001.6	-0000.5	-00001.5	0000.4	-01.230		030.00
000.0	-015.0	-0001.1	006.22	-0001.6	-0002.2	00001.3	-0001.6	-01.454		030.00
000.0	-030.0	-0001.1	005.97	-0001.8	-0002.9	00002.2	-0004.9	-01.636		030.00

Table 5. (continued)

UNIVERSITY OF MARYLAND
WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO 060 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
000.0	-060.0	-0001.2	002.78	-0001.5	-0002.5	00002.0	-0009.8	-01.250		030.00
000.0	-090.0	-0000.9	-000.50	0000.5	-0000.4	00001.7	-0010.3	00.555		030.00
000.0	-120.0	0000.4	-003.68	0000.3	0000.8	00001.5	-0008.6	-00.750		030.00
000.0	-150.0	0001.0	-007.25	0001.1	-0000.4	-00000.1	-0004.6	-01.100		030.00
000.0	-180.0	0001.6	-005.33	-0000.9	0000.0	-00000.9	0000.0	00.562		030.00

RUN NO TEST NO 049 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
015.0	-000.0	0000.4	006.02	-0002.0	-0000.7	-00001.6	0000.7	05.000		030.00
015.0	-015.0	0000.4	005.73	-0001.8	-0002.0	00001.1	-0001.7	04.500		030.00
015.0	-030.0	0000.5	005.39	-0002.0	-0002.6	00002.5	-0004.7	04.000		030.00

RUN NO TEST NO 061 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
015.0	-060.0	-0000.6	002.79	-0001.5	-0002.4	00002.8	-0010.0	-02.500		030.00
015.0	-090.0	-0001.0	-000.57	0000.6	-0000.4	00001.7	-0009.9	00.600		030.00
015.0	-120.0	-0000.2	-002.90	0000.2	0001.3	00000.5	-0008.7	01.000		030.00
015.0	-150.0	0000.3	-006.76	0000.3	0000.2	-00001.1	-0004.8	-01.000		030.00
015.0	-180.0	0000.9	-005.72	-0002.2	-0000.2	-00000.9	0000.5	02.444		030.00

Table 5. (continued)

UNIVERSITY OF MARYLAND

WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO 062 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
030.0	000.0	0002.2	004.44	-0001.6	-0000.9	-00001.1	0000.6	00.818		030.00
030.0	-015.0	0002.3	004.32	-0001.4	-0001.4	00000.9	-0001.8	00.608		030.00
030.0	-030.0	0002.3	004.12	-0001.6	-0002.2	00002.3	-0004.9	00.695		030.00
030.0	-060.0	0000.5	002.18	-0001.0	-0002.1	00003.3	-0009.9	02.000		030.00
030.0	-090.0	-0001.2	-000.47	0000.6	-0000.3	00001.8	-0009.7	00.666		030.00
030.0	-120.0	-0000.3	-002.17	0000.0	0001.5	-00000.2	-0008.5	00.000		030.00
030.0	-150.0	-0000.3	-005.91	-0000.4	0000.8	-00002.6	-0005.7	-01.333		030.00
030.0	-180.0	-0000.3	-005.67	-0002.4	-0000.2	-00000.5	0000.4	-08.000		030.00

RUN NO TEST NO 063 684 — BODY AXES 10/25/74 — 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
045.0	000.0	0003.3	002.86	-0001.5	-0001.0	-00001.3	0000.5	00.454		030.00
045.0	-015.0	0003.5	002.81	-0001.2	-0001.3	00000.3	-0001.6	00.342		030.00
045.0	-030.0	0003.5	002.83	-0001.0	-0002.0	00002.3	-0004.8	00.285		030.00
045.0	-060.0	0001.1	001.56	-0000.3	-0001.7	00003.9	-0009.9	00.272		030.00
045.0	-090.0	-0001.1	-000.57	0000.8	-0000.1	00001.7	-0009.6	00.727		030.00
045.0	-120.0	-0000.8	-001.38	0000.3	0001.4	-00000.7	-0008.7	00.375		030.00
045.0	-150.0	-0001.5	-004.20	0000.2	0000.9	-00003.2	-0005.9	00.133		030.00
045.0	-180.0	-0001.6	-004.28	-0001.6	-0000.6	-00000.6	0000.1	-01.000		030.00

Table 5. (continued)

UNIVERSITY OF MARYLAND

WIND TUNNEL OPERATIONS DEPT.

RUN NO TEST NO BODY AXES 10/25/74

064 684 00 95 03 02 44 00 00 00

AA	AY	L	D	PM	YM	RM	SF	C CP	L D	Q
060.0	000.0	0004.0	002.07	-0000.4	-0001.0	-00000.6	0000.5	00.100		030.00
060.0	-015.0	0004.0	001.74	-0000.5	-0001.4	00000.1	-0001.1	00.125		030.00
060.0	-030.0	0004.2	001.74	-0000.5	-0001.7	00002.2	-0003.9	00.119		030.00
060.0	-060.0	0001.6	000.68	0000.3	-0001.2	00003.9	-0009.2	-00.187		030.00
060.0	-090.0	-0000.9	-000.77	0000.7	0000.1	00001.6	-0009.5	00.777		030.00
060.0	-120.0	0001.2	-000.70	0000.7	0001.2	-00001.0	-0008.6	00.583		030.00
060.0	-150.0	-0002.7	-002.03	0001.0	0000.9	-00003.4	-0006.4	00.370		030.00
060.0	-180.0	-0002.4	-002.43	-0000.6	-0000.4	-00000.5	0000.1	-00.250		030.00

Table 6. Average Seat Force Areas and Moment Volumes for Human Subjects at $q = 30\ lb/ft^2$

Pitch Angle (Deg)	Yaw Angle (Deg)	Lift	Drag	Pitching Moment	Yawing Moment	Rolling Moment	Side Force
30	0	2.01	4.35	-1.88	-0.63	-1.12	0.40
45	0	2.88	2.78	-1.47	-0.72	-0.82	0.38
60	0	3.93	1.93	-0.43	-0.75	-0.78	0.41
30	-15	2.11	4.53	-1.58	-1.56	1.05	-1.97
45	-15	3.53	2.90	-1.00	-1.62	0.54	-1.74
60	-15	4.08	1.74	-0.35	-1.35	0.18	-0.93
30	-30	2.21	4.21	-1.33	-2.75	1.70	-5.20
45	-30	3.56	2.95	-0.63	-2.55	1.91	-4.63
60	-30	4.24	1.49	-0.20	-2.31	2.21	-3.85

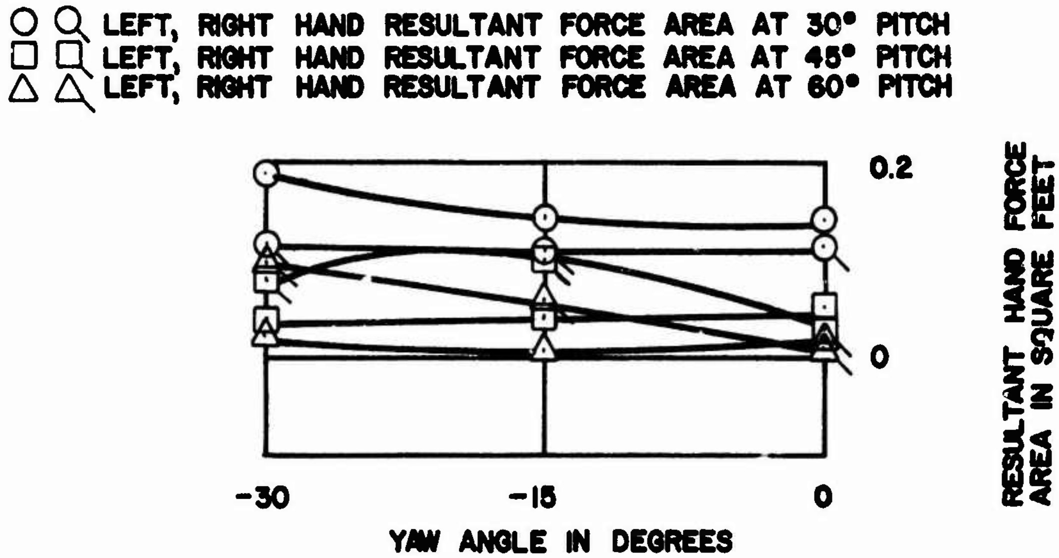


FIGURE 9 VARIATION OF RESULTANT HAND FORCE AREA WITH YAW ANGLE

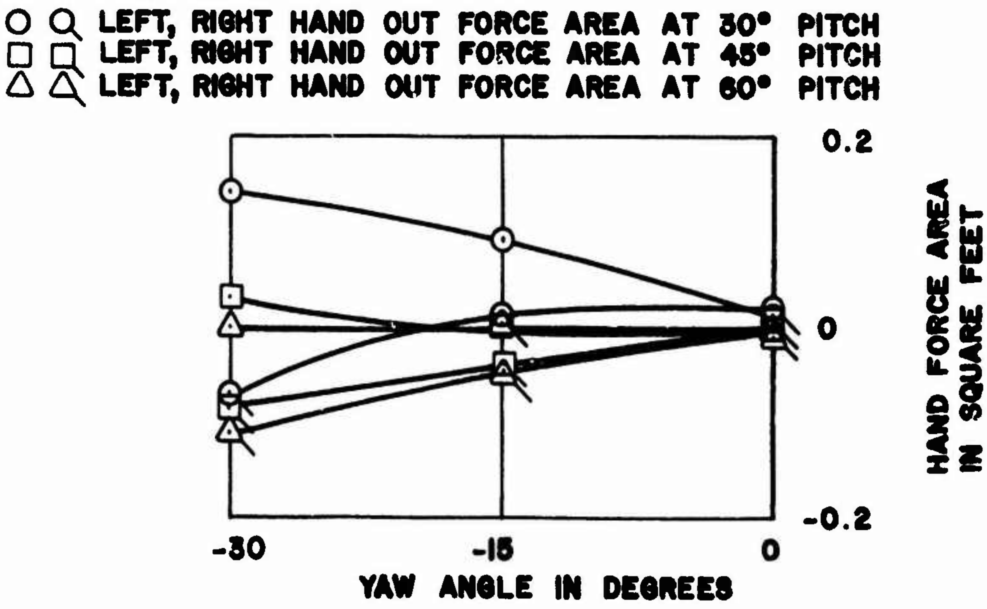


FIGURE 10 VARIATION OF HAND OUT FORCE AREA WITH YAW ANGLE
(OUT IS POSITIVE)

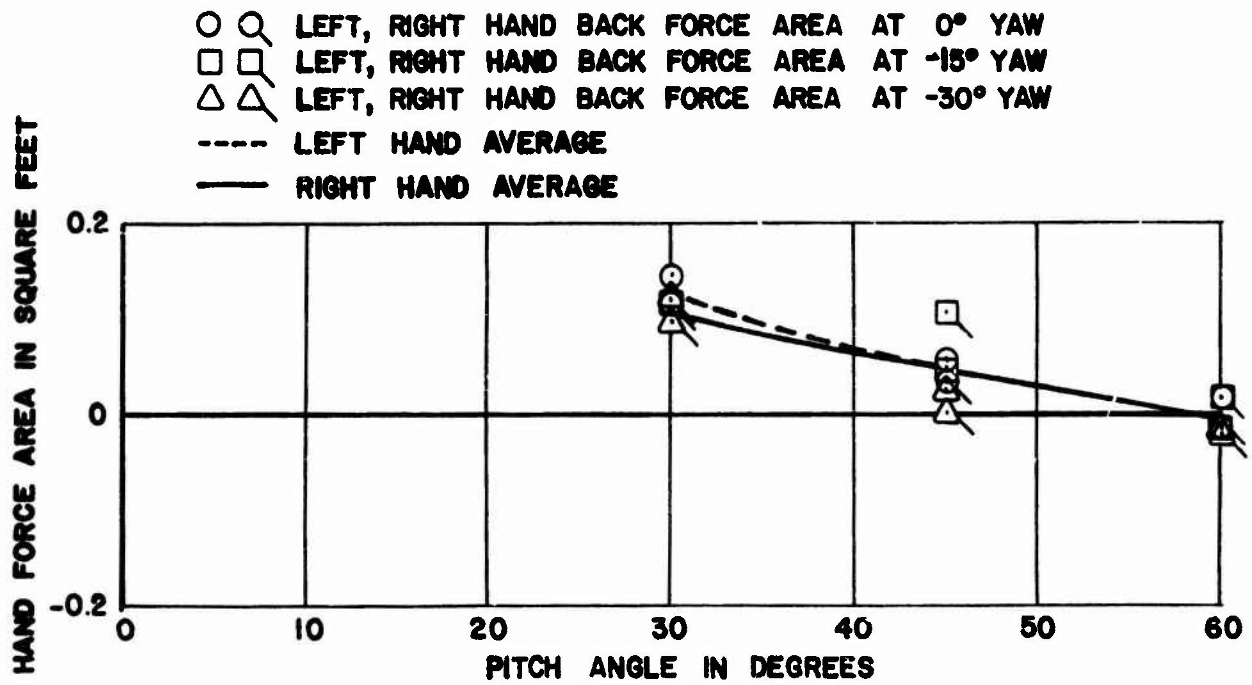


FIGURE 11 VARIATION OF HAND BACK FORCE AREA WITH PITCH ANGLE. (BACK IS POSITIVE)

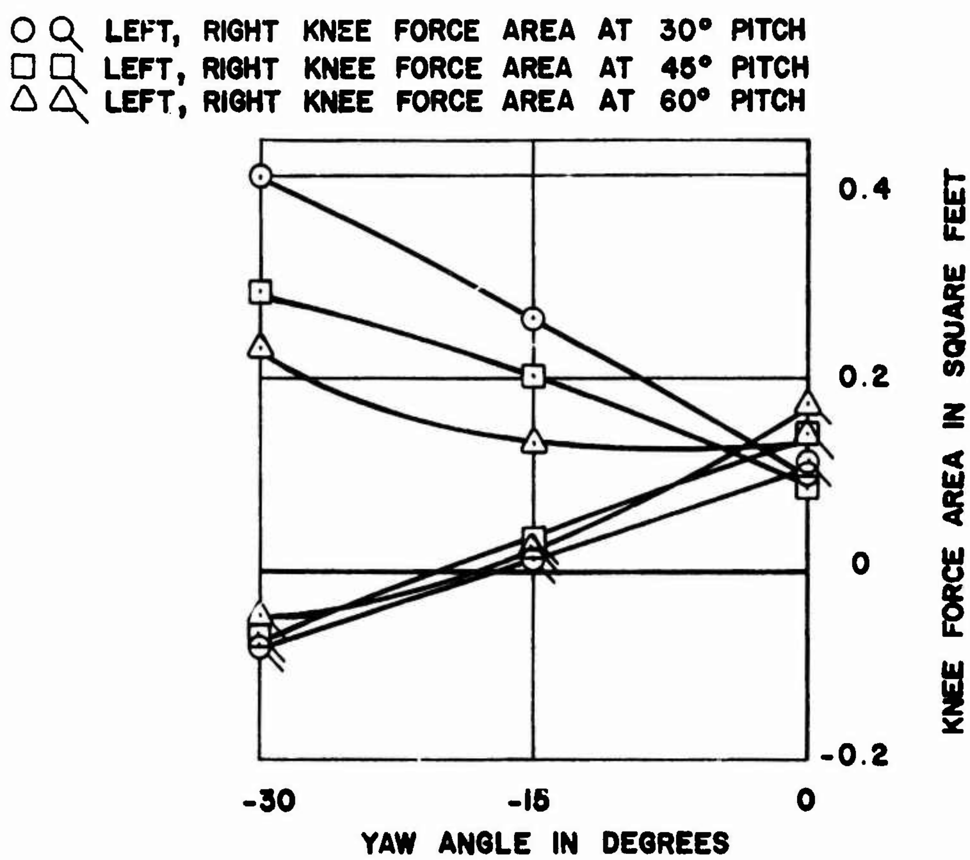


FIGURE 12 VARIATION OF KNEE OUT FORCE AREA WITH YAW ANGLE. (OUT IS POSITIVE)

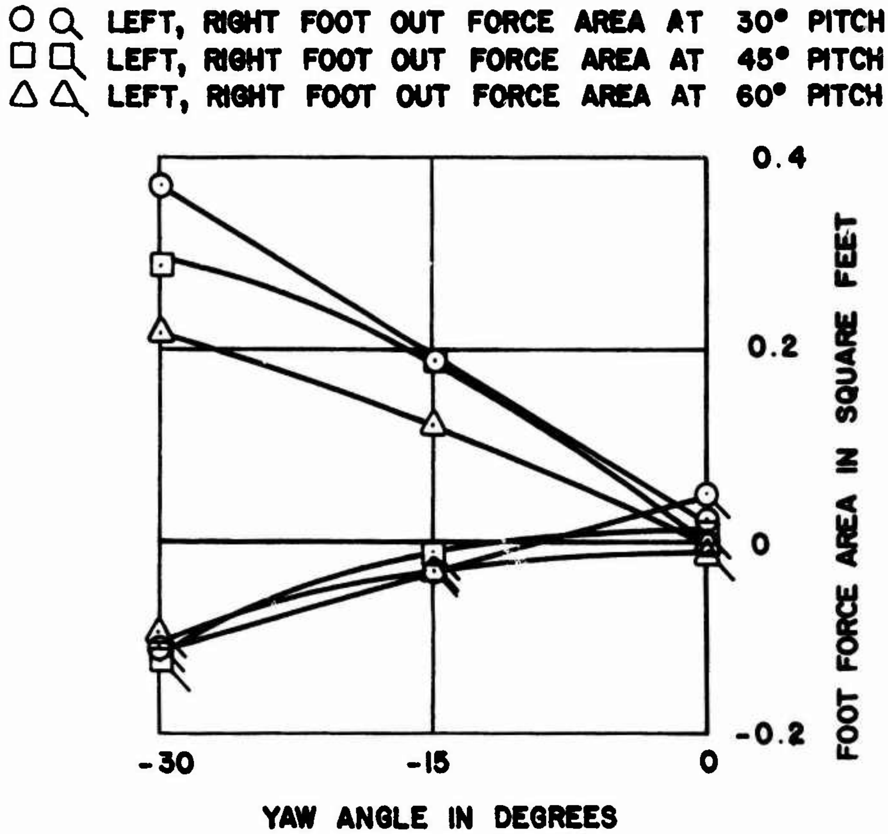


FIGURE 13 VARIATION OF FOOT OUT FORCE AREA WITH YAW ANGLE. (OUT IS POSITIVE)

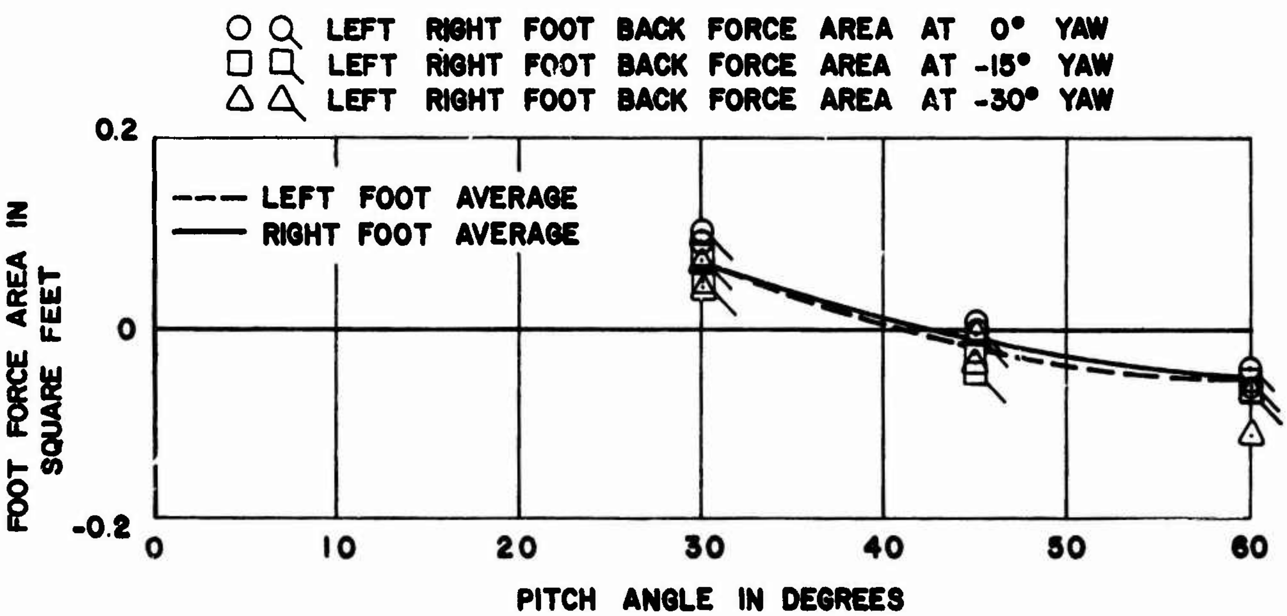


FIGURE 14 VARIATION OF FOOT BACK FORCE AREA WITH PITCH ANGLE. (BACK IS POSITIVE)

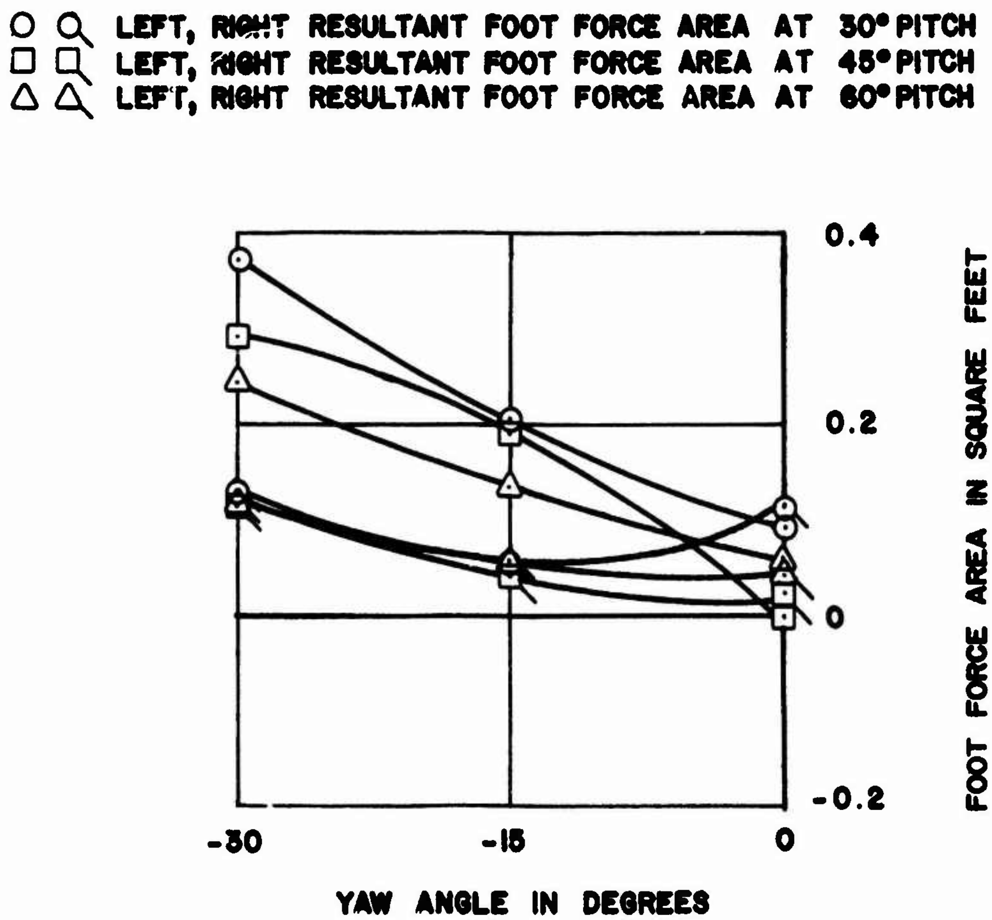


FIGURE 15 VARIATION OF RESULTANT FOOT FORCE AREA WITH YAW ANGLE

difference at 60° being approximately 40% that of the value at 0° pitch (Figure 12).

The outward force at the foot is not appreciably affected by the pitch angle at 0° yaw. However, as yaw is increased, the outward force at the foot is increased (Figure 13).

The rearward force on the foot is reduced progressively with increasing pitch becoming zero at 45° and about -.05 ft^2 (= forward force) at 60° (Figure 14). This is experienced by the subject as a tendency to lift the leg off any backward restraint and, when combined with side force, to fold them to one side over the arm of the seat. Figure 15 shows the resultant force at the foot to be only 0.1 ft^2, at 60° pitch, reduced from 0.4 ft^2 at 30° and 0.51 ft^2 at zero pitch (from Reference 1.)

On the whole, the dislodgement forces on the limbs are reduced at high angles of pitch, with and without large yaw angles.

Helmet Lift and Side Force

The data is presented in Table 2.

Previous work (Reference 1) indicated that the aerodynamical forces tending to remove the helmet were due to low pressures on the outside, rather than ram pressure between the head and the helmet. Therefore, as a means of reducing these forces, spoiling the flow outside would seem to be more effective than attempts to seal the inner space against the dynamic pressure.

Helmet Lift Force

Figure 16 shows the lift force area on the helmet over the pitch range -15° to +60°. In the symmetrical case, the air flow is evidently sensitive to pitch angle because the lift increases with pitch for small angles, then falls away abruptly above +15°. A small amount of yaw either way (±15°) makes the lift insensitive to pitch, at practically constant values up to 45°.

Fitting the Helmet Loss Preventer changes the lift force drastically. The effect could be explained merely as a 30° change in pitch angle because the ±15 yaw values are grouped with the symmetrical case in a fairly linear relationship with +15° pitch corresponding to -15° for the unadorned helmet. On this data, it is difficult to explain how the spoiler works, but it is undoubtedly effective in reducing the lift over the ±15° pitch range.

The Loss Preventer has little effect on the side force under yaw (Figure 17) and tends to dominate in the resultant force comparison of Figure 18.

Forces and Moments with Human Occupants

During the limb dislodgements, the overall seat force and moment data was taken by the standard procedure. In the light of more extensive tests with the dummy

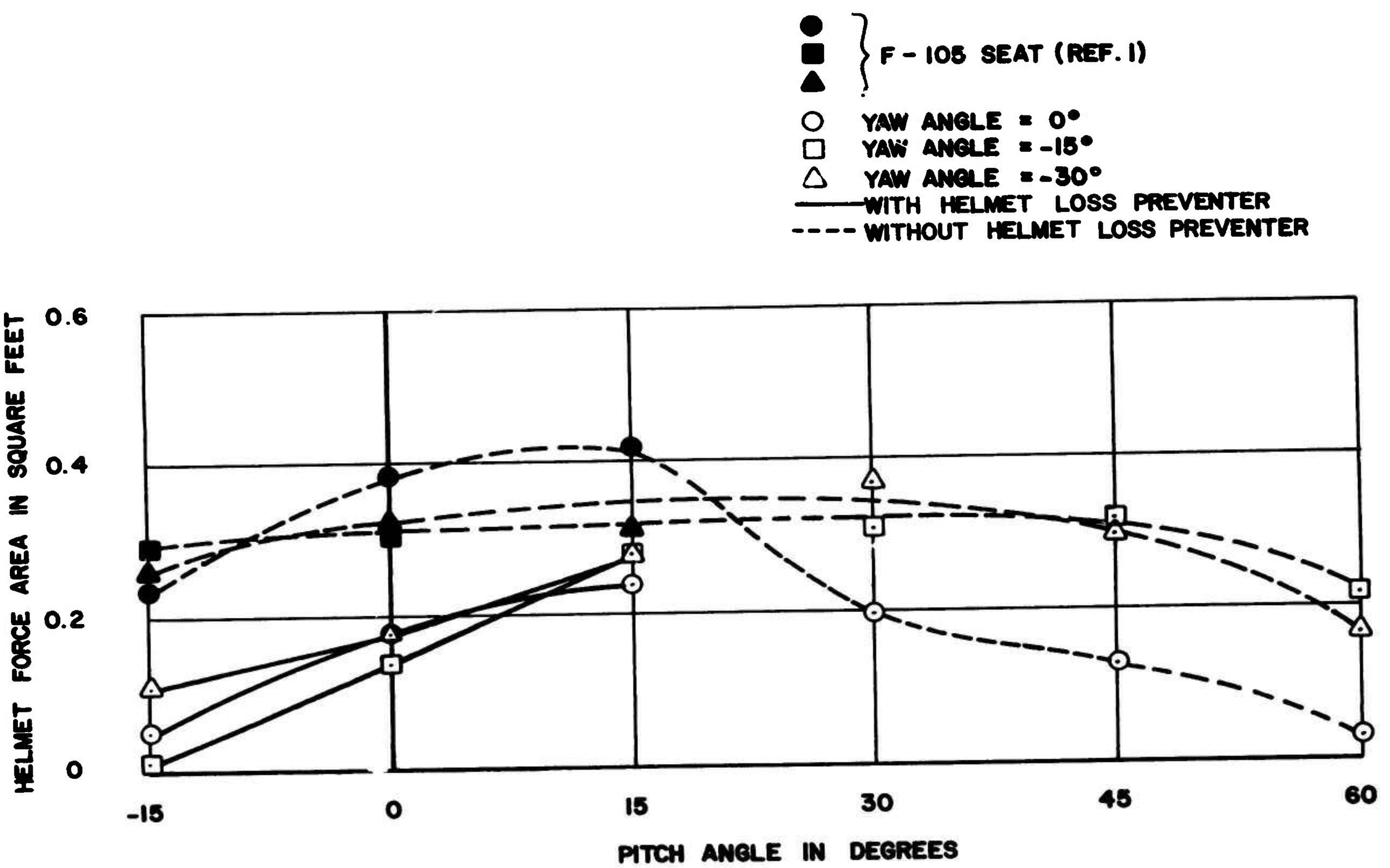


FIGURE 16 VARIATION OF HELMET LIFT FORCE AREA WITH PITCH ANGLE. (UP IS POSITIVE)

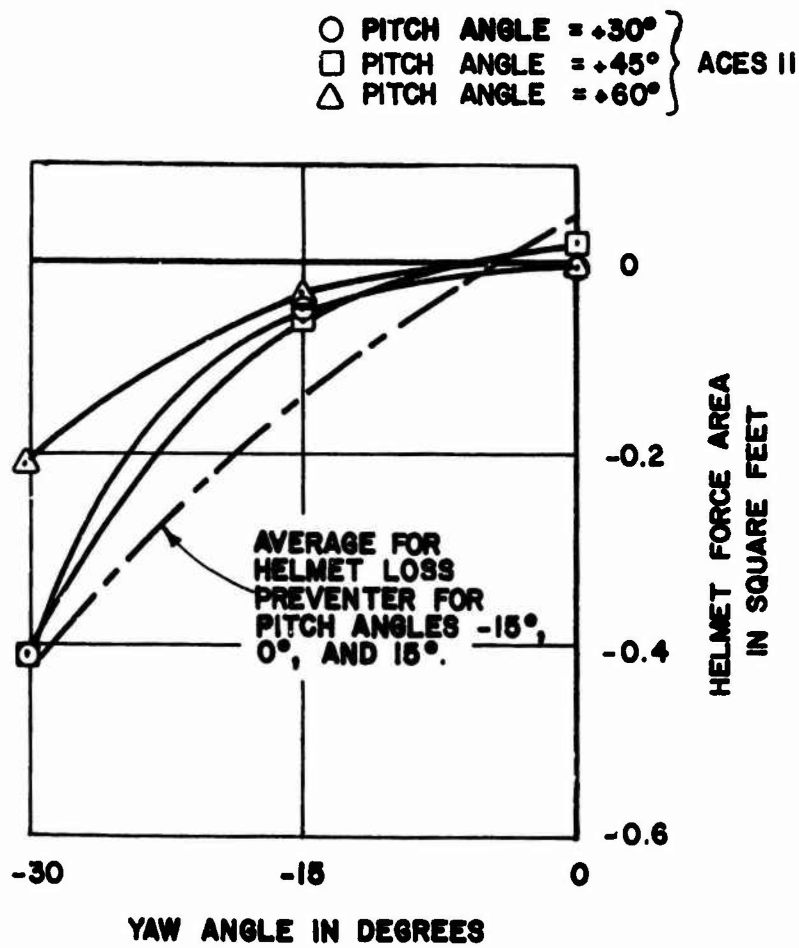


FIGURE 17 VARIATION OF HELMET SIDE FORCE AREA WITH YAW ANGLE. (RIGHT IS POSITIVE)

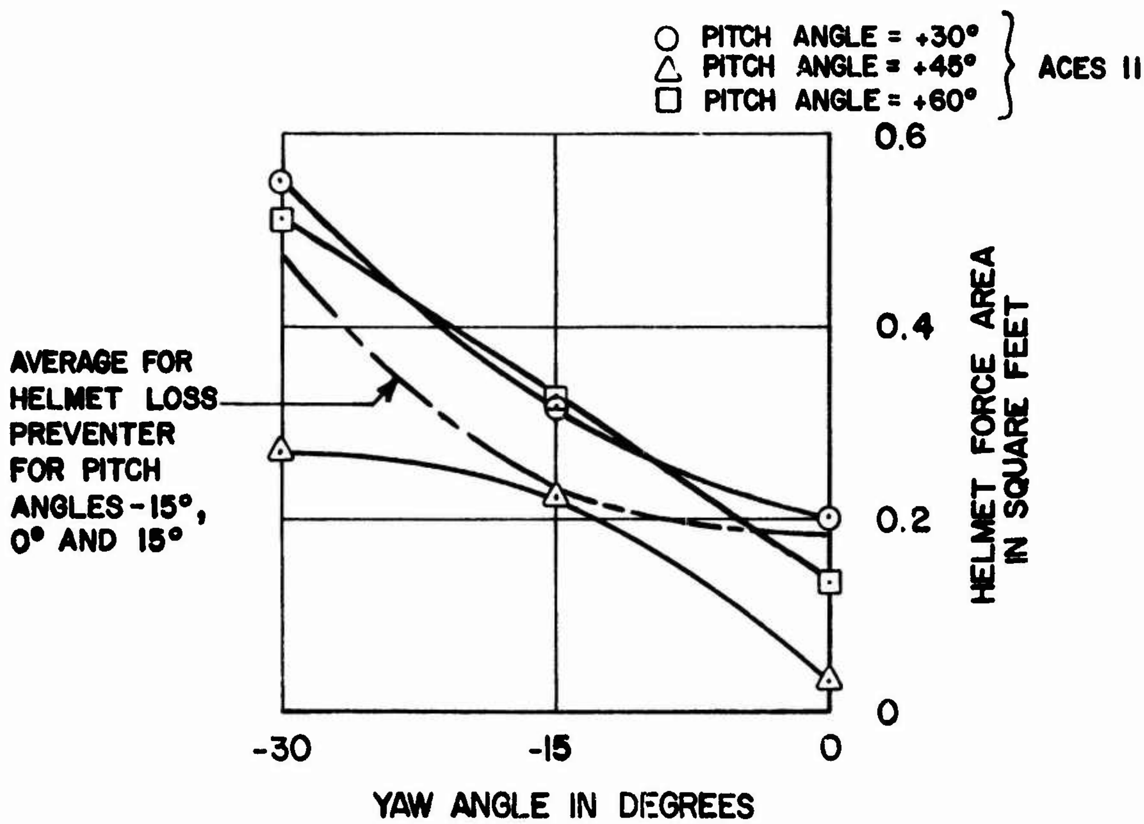


FIGURE 18 VARIATION OF RESULTANT HELMET FORCE AREA WITH YAW ANGLE.

occupants, the results for the humans lose some of their uniqueness. However, they do show good conformity with the later results and with the earlier results (with humans) from Reference 1. Figures 19 through 24 show the curves for the respective forces and moments. The values plotted are the average for the three test subjects, from Table 6, so that their individual traits are suppressed. The effect of CG variation between individuals does not appear in this method of test because moments are all expressed with respect to a nominal CG position. Therefore, the individuals are distinguished only by their size (which in subsequent tests is shown to make very little difference) and by peculiarities of dress, equipment or posture. These have been largely suppressed by the averaging process.

Forces and Moments with Dummy Occupants

Two anthropomorphic dummies were available for the tests. These were the 5% dummy (smaller than 95% of the air crew population) and the 95% (larger than 95% of the air crew). The difference in size between these two enables the effect of size to be examined. The fact that the seat size is not changed means that there is a change in form of the dummy-seat combination.

The dummies were used in order to compare the static forces and moments of the seat/man combination with human subjects. Pitch angles were taken from nose down (-15°) to tipped back (+60°), the limits possible with the floor mounted pedestal. Yaw angles were taken round to about-face (180°).

The variation around the complete cycle is apparently sinusoidal for the side force at one "wave length" per complete rotation. The yawing and rolling moments show signs of modulation at 2 cycles per revolution, suggesting that the body has 4 corners, rather than 2 edges, in this regard. The pitching moment variation over 75° of pitch looks like part of a 2-cycle per turn variation. This may be important in considering stability, since the angular range over which stability can be maintained may be somewhat narrow.

From the measurements of lift, drag, and side forces, only secondary effects of the differences between these two dummies comes through in the data. The lift forces, Figures 25 and 26, are practically identical. Drag forces, Figures 27 and 28, show small differences. The larger dummy has smaller drag in front view, larger drag in rear view, and a small anti-drag (= tunnel side force) at 90° yaw. These differences are anomalous in regard to size alone, but they could be explained by the seat being better filled by the larger dummy and therefore less bluff in front. Similar small differences are discernible in the side force measurements, Figures 29 and 30.

Differences between the moment curves are more marked but still not explicable in terms of size alone. In pitch, the only appreciable differences in magnitude occur in the nose-down moments at 180° yaw, those of the 95% dummy (Figure 32) being 50% smaller over the -15° to 0° range of pitch setting. Yawing moments are almost identical. Figures 33 and 34 show the same quasi-sinusoidal curve over 180° of yaw.

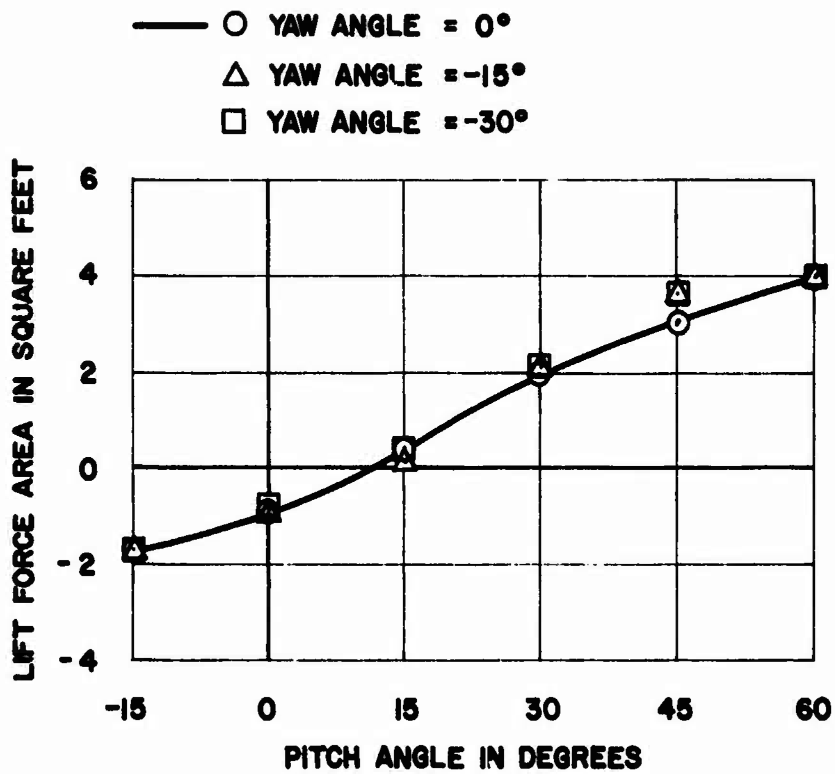


FIGURE 19 ACES II SEAT LIFT FORCE AREA AS A FUNCTION OF PITCH ANGLE FOR VARIOUS YAW ANGLES.
AVERAGE OF HUMAN SUBJECTS; $q = 30\ LB/FT^2$.

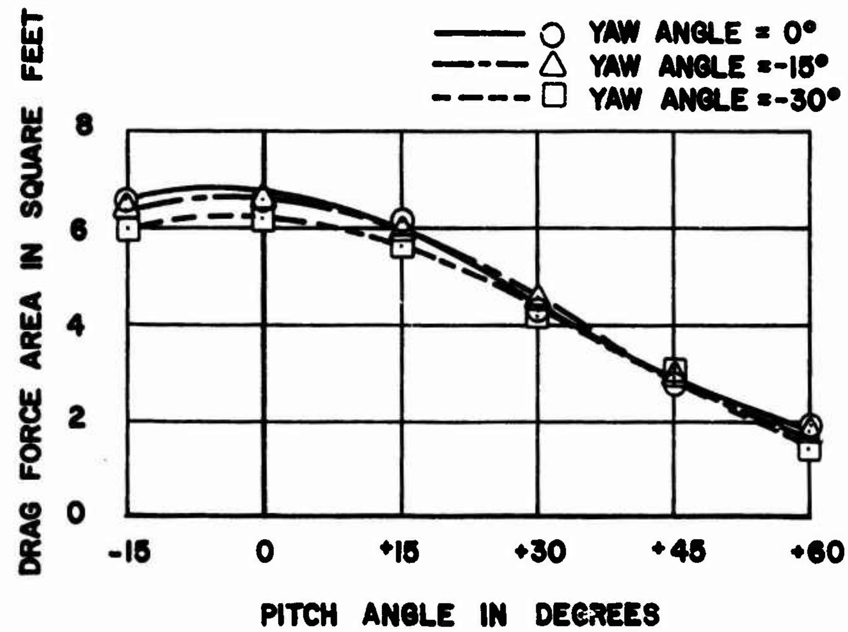


FIGURE 20 ACES II SEAT DRAG FORCE AREA AS A FUNCTION OF PITCH ANGLE FOR VARIOUS YAW ANGLES.
AVERAGE OF HUMAN SUBJECTS; $q = 30\ LB/FT^2$.

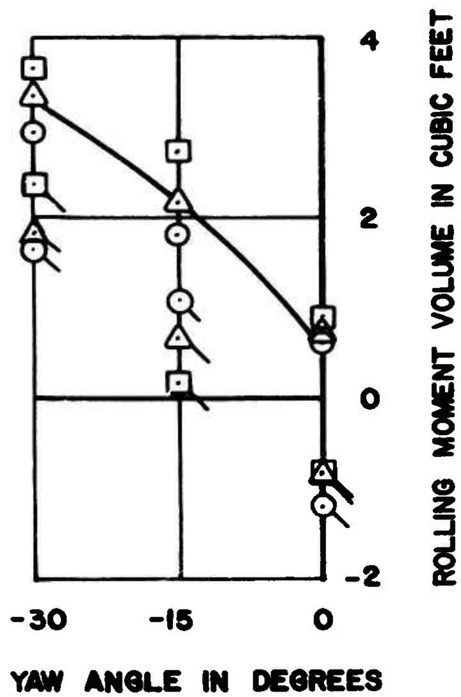


FIGURE 21 ACES II SEAT ROLLING MOMENT VOLUME AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES. AVERAGE OF HUMAN SUBJECTS; $q = 30\ LB/FT^2$

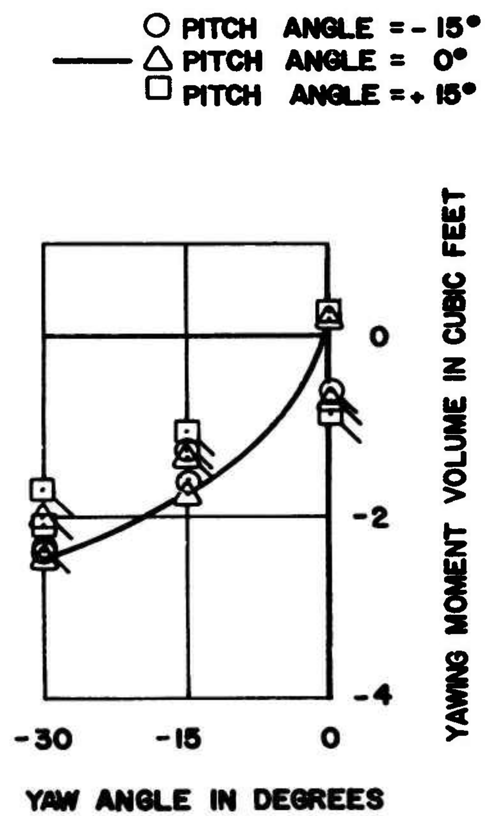


FIGURE 22 ACES II SEAT YAWING MOMENT VOLUME AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES. AVERAGE OF HUMAN SUBJECTS; $q = 30\ LB/FT^2$.

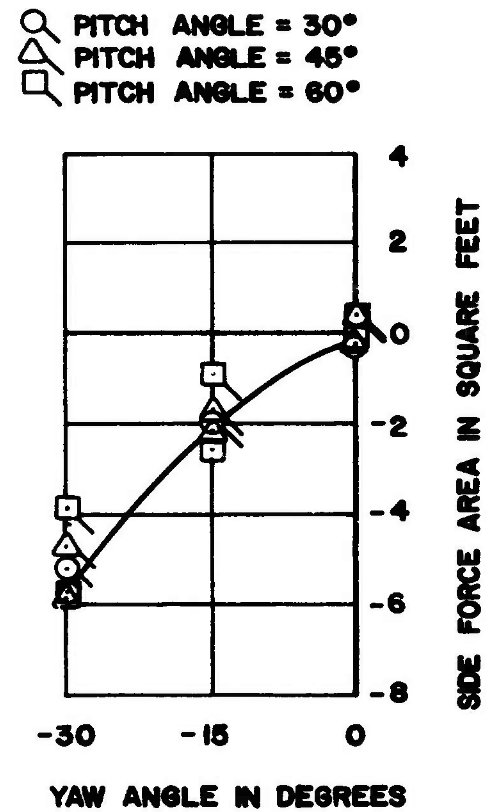


FIGURE 23 ACES II SEAT SIDE FORCE AREA AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES. AVERAGE OF HUMAN SUBJECTS; $q = 30\ LB/FT^2$.

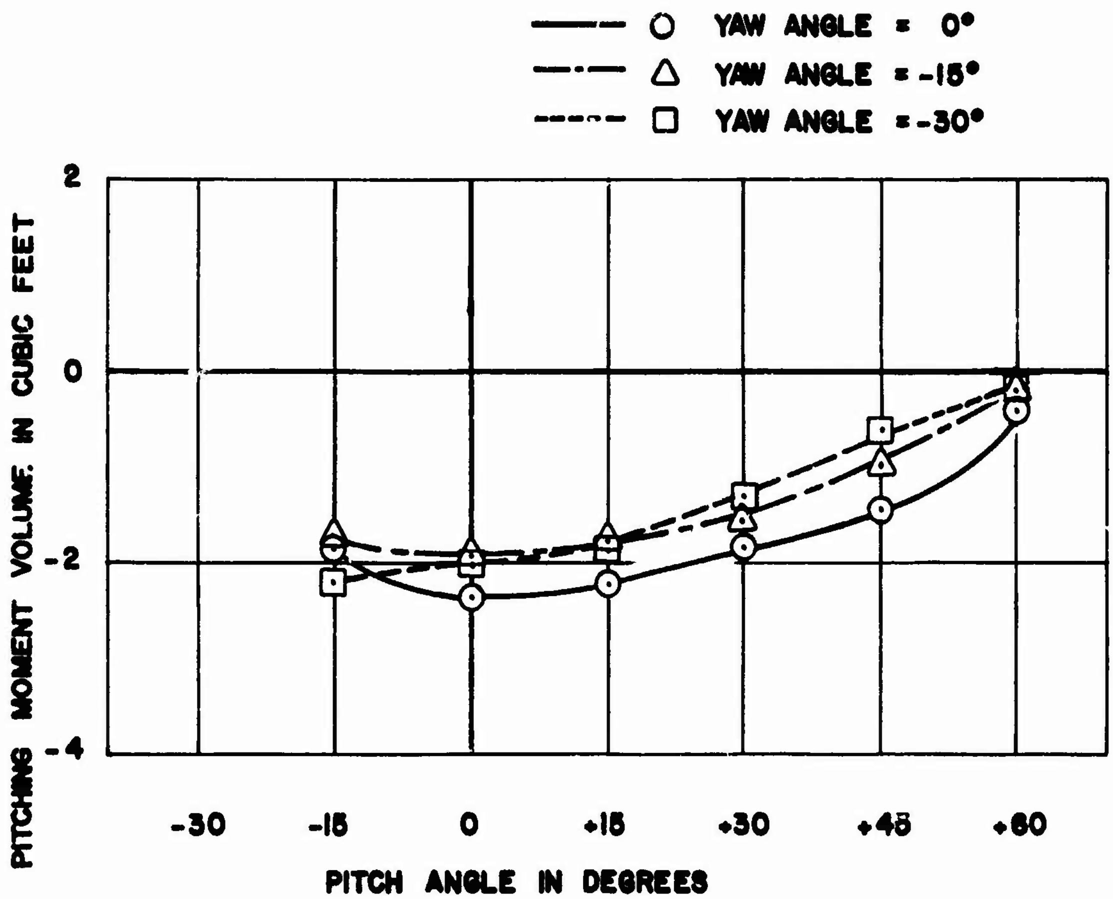


FIGURE 24 ACES II SEAT PITCHING MOMENT AS A FUNCTION OF PITCH ANGLE FOR VARIOUS YAW ANGLES. AVERAGE OF HUMAN SUBJECTS; $q = 30\ LB/FT^2$.

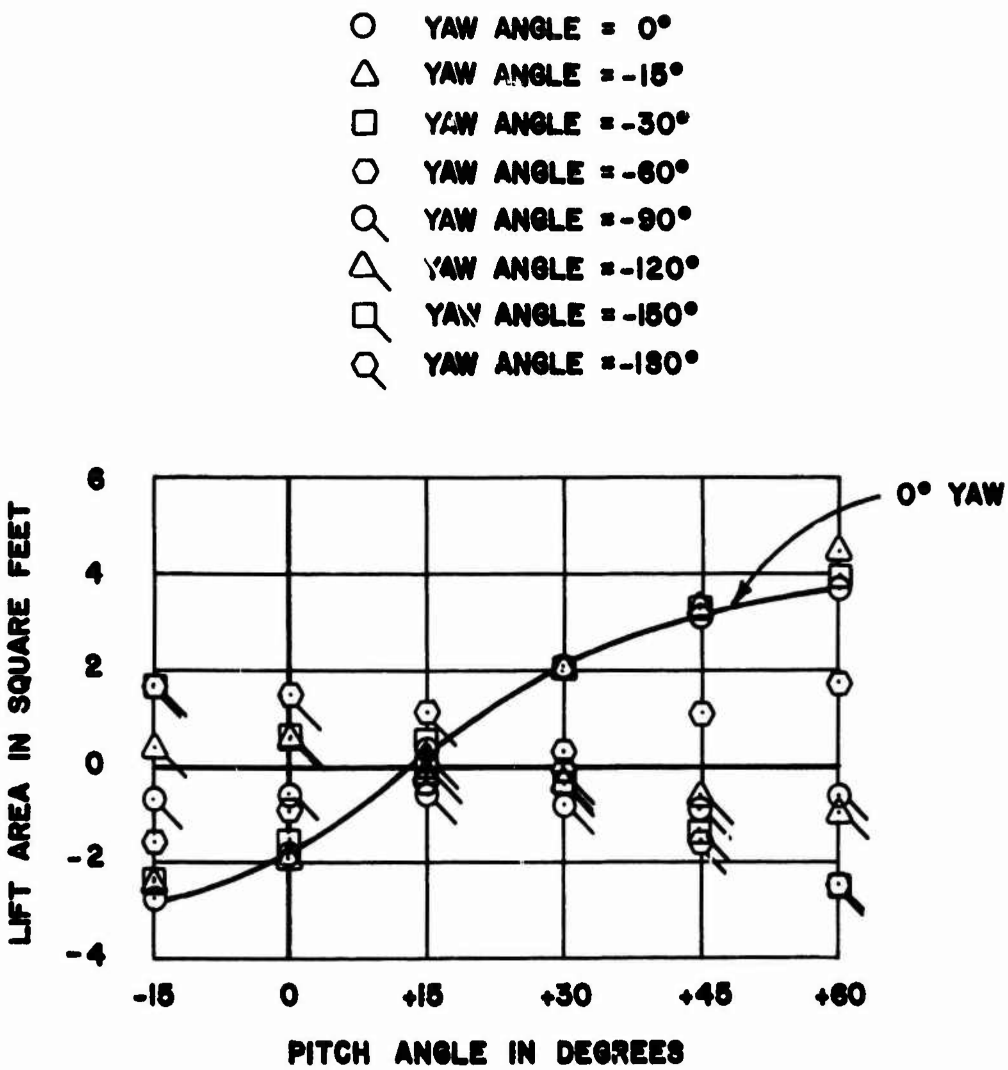


FIGURE 25 ACES II SEAT LIFT FORCE AREA AS A FUNCTION OF PITCH ANGLE FOR VARIOUS YAW ANGLES.
SUBJECT: 5% ANTHROPOMORPHIC DUMMY; $q = 30$ LB/FT^2.

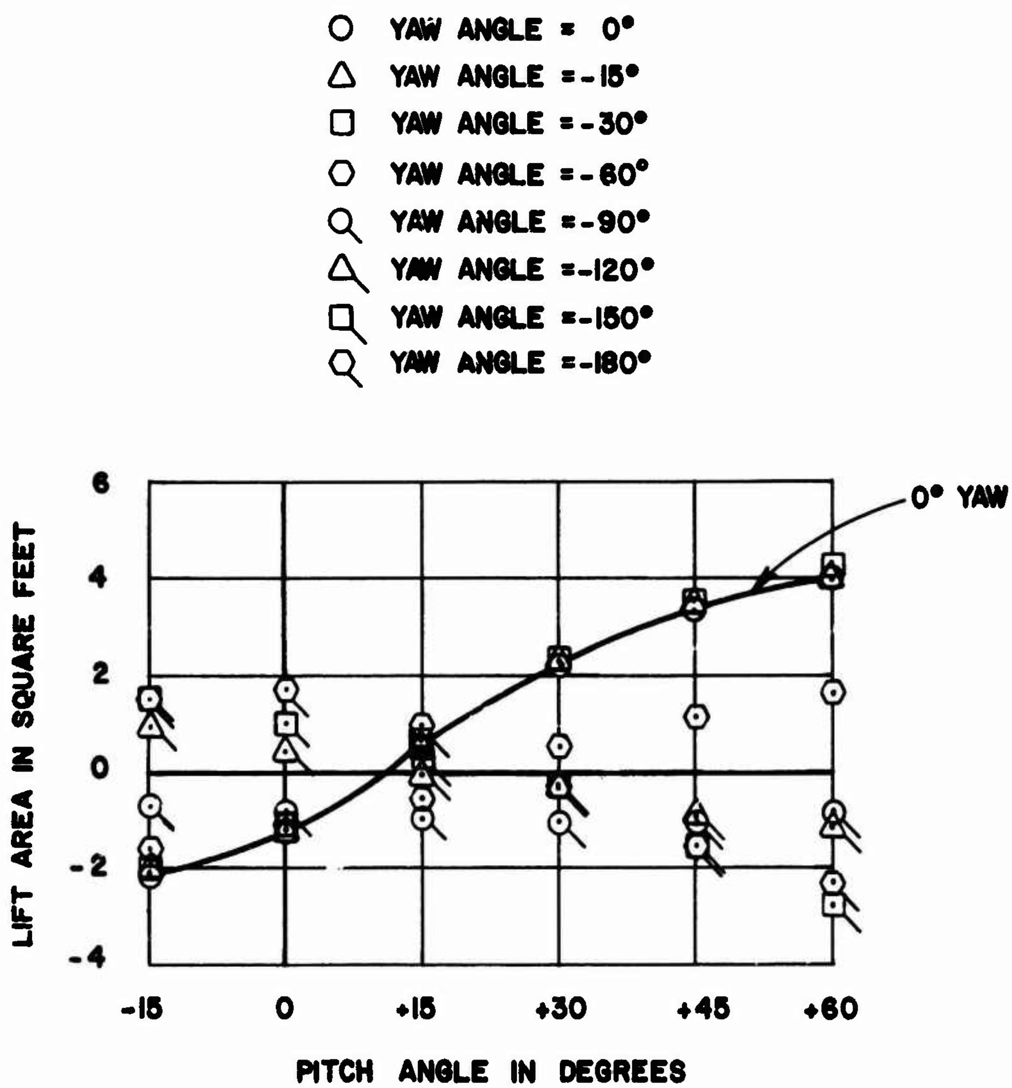
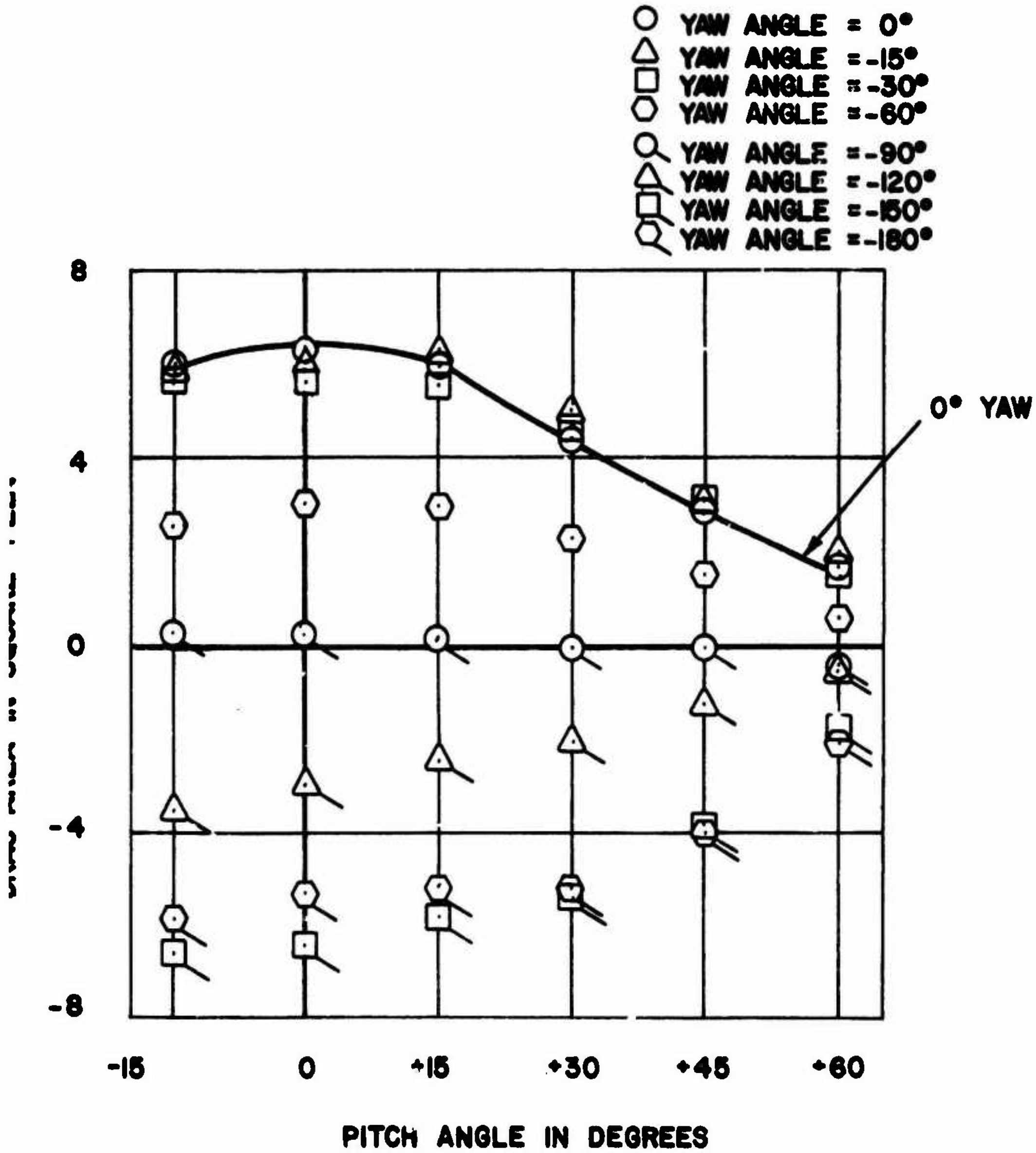


FIGURE 26 ACES II SEAT LIFT FORCE AREA AS A FUNCTION OF PITCH ANGLE FOR VARIOUS YAW ANGLES.
SUBJECT: 95 % ANTHROPOMORPHIC DUMMY; $q = 30$ LB/FT^2



URE 27 ACES II SEAT DRAG FORCE AREA AS A FUNCTION OF PITCH ANGLE FOR VARIOUS YAW ANGLES.
SUBJECT: 5 % ANTHROPOMORPHIC DUMMY; q = 30 LB/FT^2

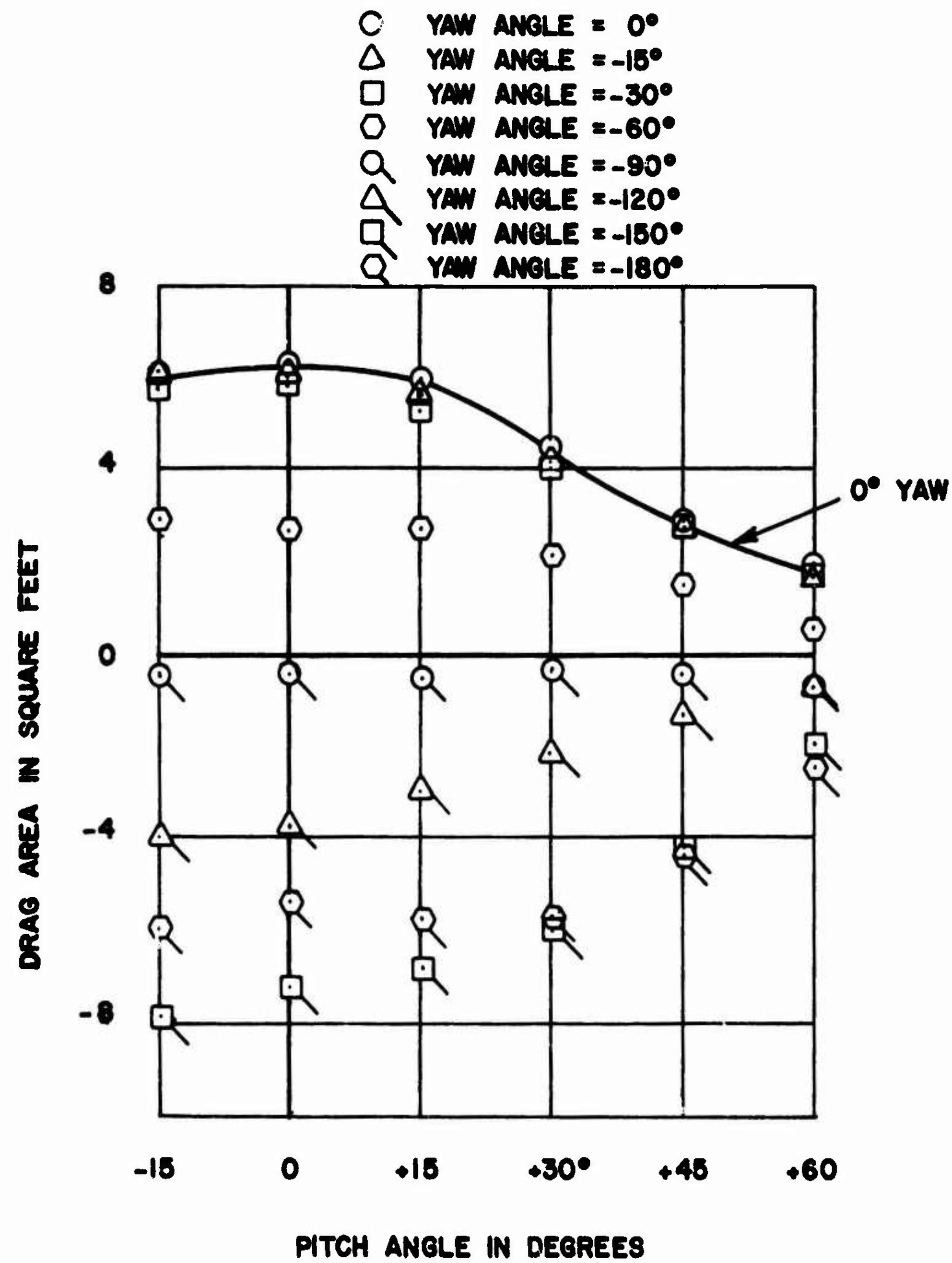


FIGURE 28 ACES II SEAT DRAG FORCE AREA AS A FUNCTION OF PITCH ANGLE FOR VARIOUS YAW ANGLES.
SUBJECT: 95 % ANTHROPOMORPHIC DUMMY; $q = 30$ LB/FT^2

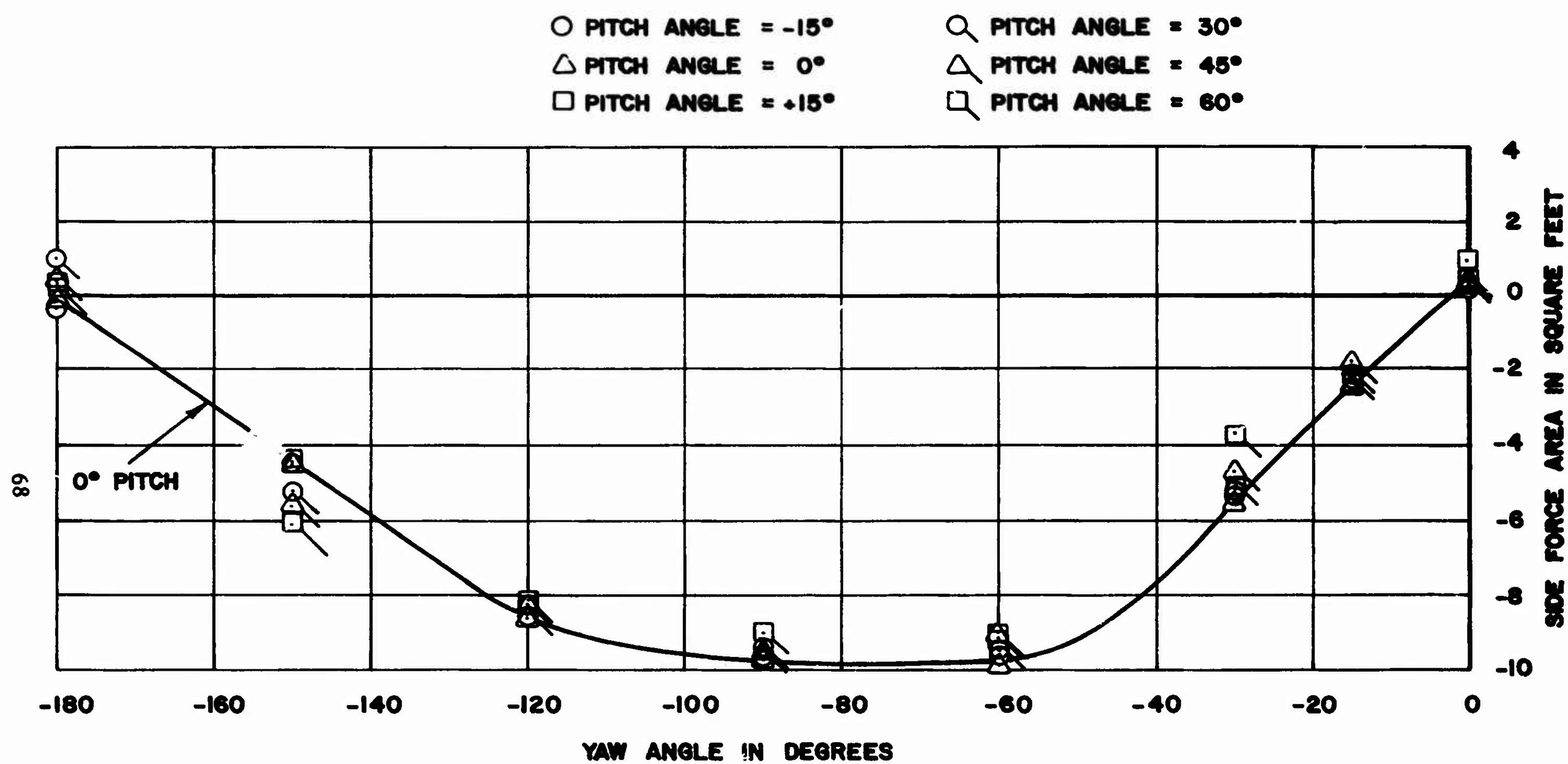


FIGURE 29 ACES II SEAT SIDE FORCE AREA AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES. SUBJECT: 5 % ANTHROPOMORPHIC DUMMY ; $q = 30\ LB/FT^2$.

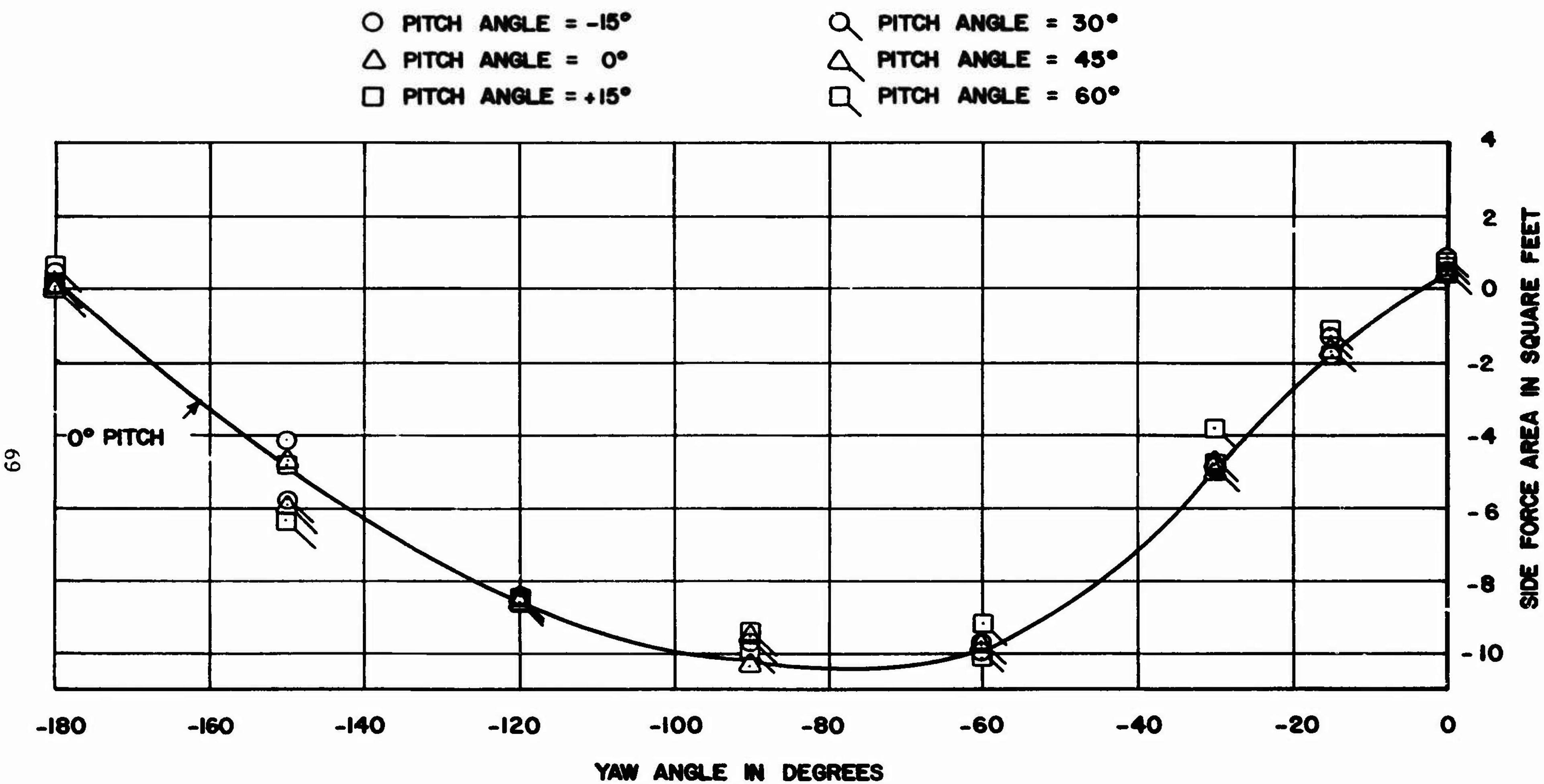


FIGURE 30 ACES II SEAT SIDE FORCE AREA AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES
SUBJECT: 95% ANTHROPOMORPHIC DUMMY; $q = 30\ LB/FT^2$.

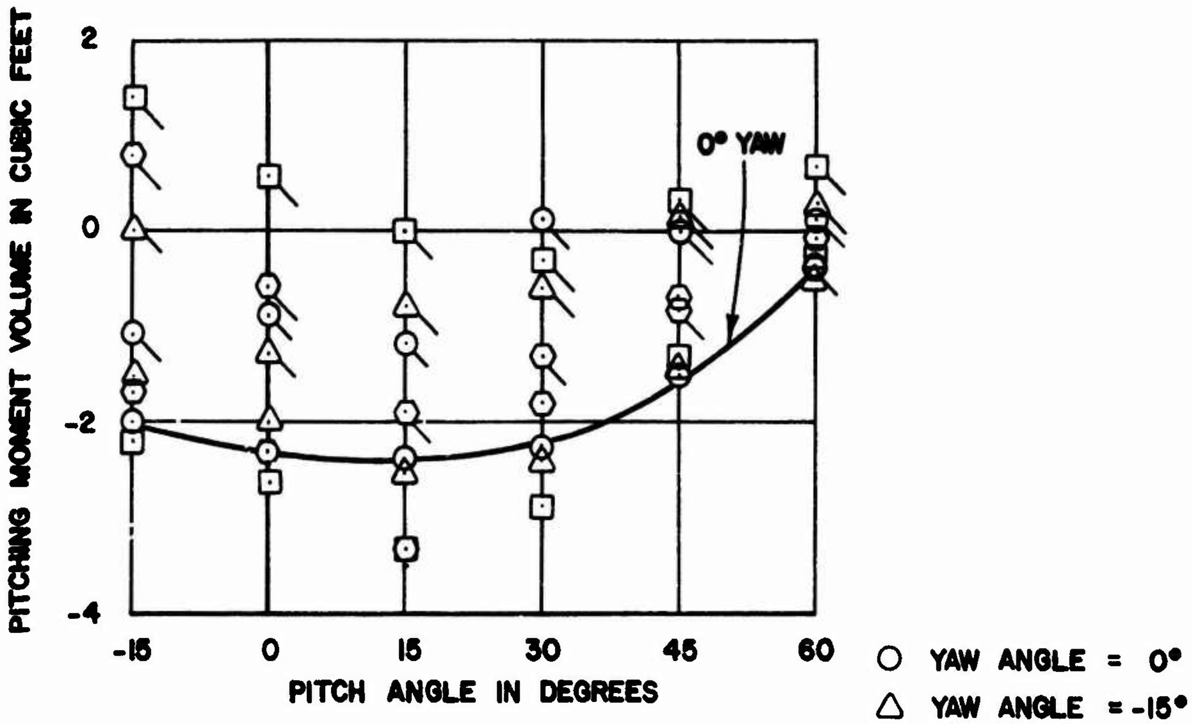


FIGURE 31 ACES II SEAT PITCHING MOMENT VOLUME VS. PITCH ANGLE FOR VARIOUS YAW ANGLES.
SUBJECT: 5% ANTHROPOMORPHIC DUMMY; q = 30 LB/FT^2

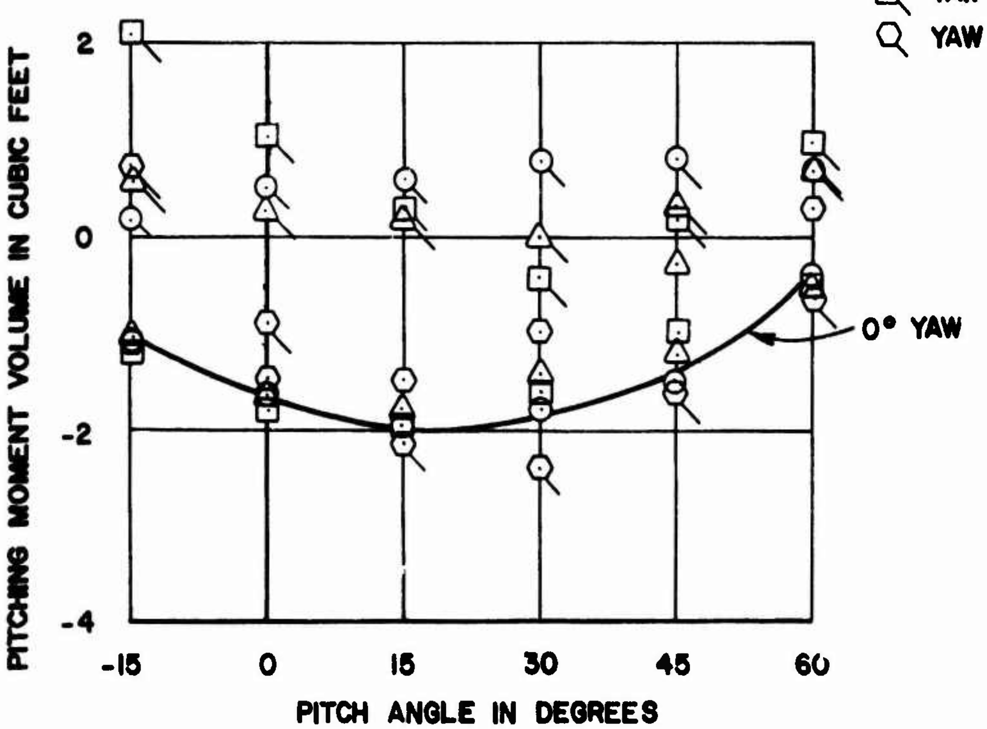


FIGURE 32 ACES II SEAT PITCHING MOMENT VOLUME VS. PITCH ANGLE FOR VARIOUS YAW ANGLES.
SUBJECT: 95% ANTHROPOMORPHIC DUMMY; q = 30 LB/FT^2

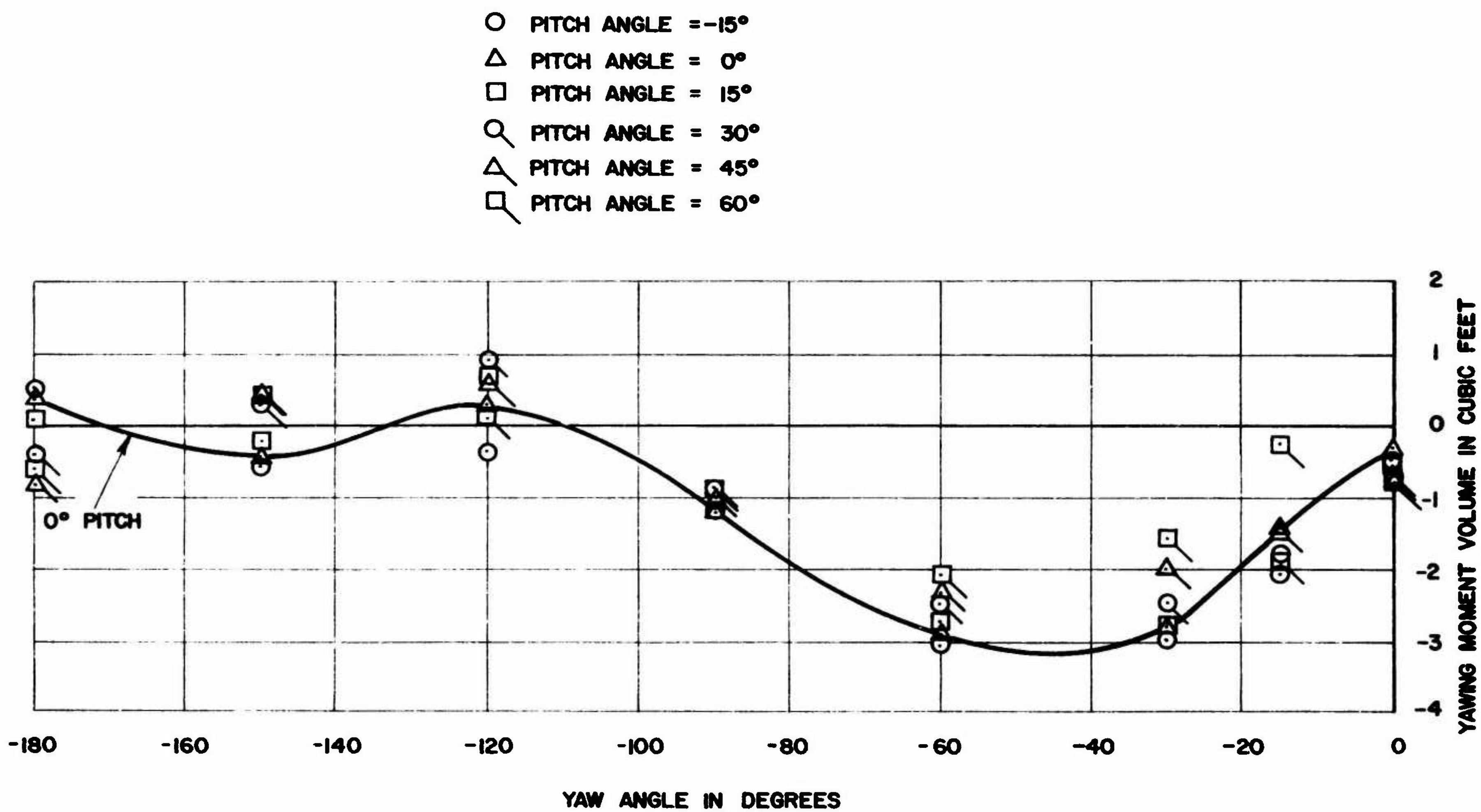


FIGURE 33 ACES II SEAT YAWING MOMENT VOLUME AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES. SUBJECT: 5% ANTHROPOMORPHIC DUMMY; $q = 30\ LB/FT^2$.

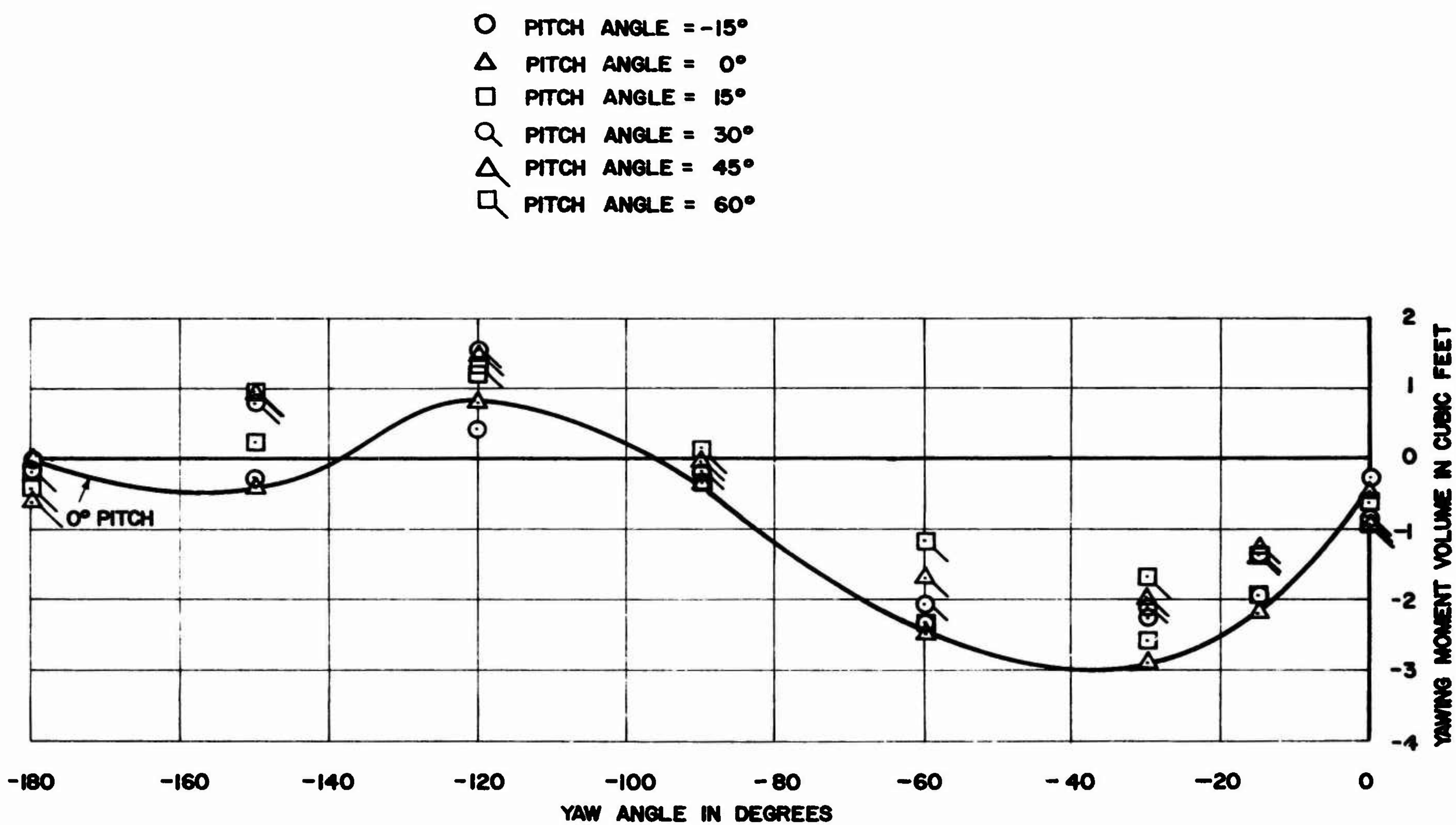


FIGURE 34 ACES II SEAT YAWING MOMENT VOLUME AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES. SUBJECT : 95 % ANTHROPOMORPHIC DUMMY; $q = 30$ LB/FT^2.

Rolling moments exhibit a curious modulation effect with varying pitch angle. Figures 35 and 36 each show pitch angle influence to be small at 0°, 90° and 180° pitch, and large between these attitudes. Figures 35 and 36 have a strong resemblance in form; in magnitude, there seems to be a bias towards the negative direction for the large dummy. This does not appear to be simply related to the larger size, although it may be a further consequence of the difference in shape of the combination of a larger dummy in the same size seat.

The moment data is referred in each case to the center of mass of the seat-dummy combination. The comparison between the two dummies is valid in this respect, but it does not cover CG variation over the range of individuals. This is discussed in the next section.

The Effect of CG Shift

The tunnel lift and moment data may easily be referred to any desired location of the center of mass of the seat-occupant combination. (The free motion of a rigid body can be expressed as a motion of its center of mass, with rotation about axes which pass through it.) From the anthropometric data, the mean CG for the seat-dummy combination has been established and marked on the seat diagram (Figure 1) for each of the two dummies. To study the effect of variation in CG location, the data was referred successively to locations displaced 2 inches rearward, up, forward, and down of the seat manufacturer's mean position. The choice of the value 2 inches is arbitrary, to cover differences in equipment and seating position as well as the anthropometric variation.

Transferring the forces to the new CG positions results in a rotation of the trim positions to new positions of pitch or yaw, and in changes in the slope as different parts of the moment curve intersect the axis of zero moment. Besides these changes, the basic moment curve shape is modified by the transformation (Figures 37 to 50). These effects are readily perceived by reference to a particular example. Figure 37 illustrates the seat at zero yaw angle. The lowest CG gives almost neutral stability ($\partial M/\partial\theta = 0$), over the range $+15° < \alpha < +45°$ with trim angle occurring at $\alpha = -15°$. The highest CG gives a negative moment with a stable position off-scale at $\alpha << -20°$. This seat, if placed gently in an airstream, would rotate nose downwards to a position between vaguely upright (lowest CG) to a fairly well defined head forward attitude for the highest CG. None of the occupants would enable it to settle in a semi-reclining feet-first position because this position is unstable in all cases and the seat would rotate away from it in either direction.

Static Stability

Static stability in each of the angular motions is defined by the condition that the moment should be zero at equilibrium and that the derivative of moment with respect to angle should be negative so that small displacements from the equilibrium position should induce restorative moments. In terms of the

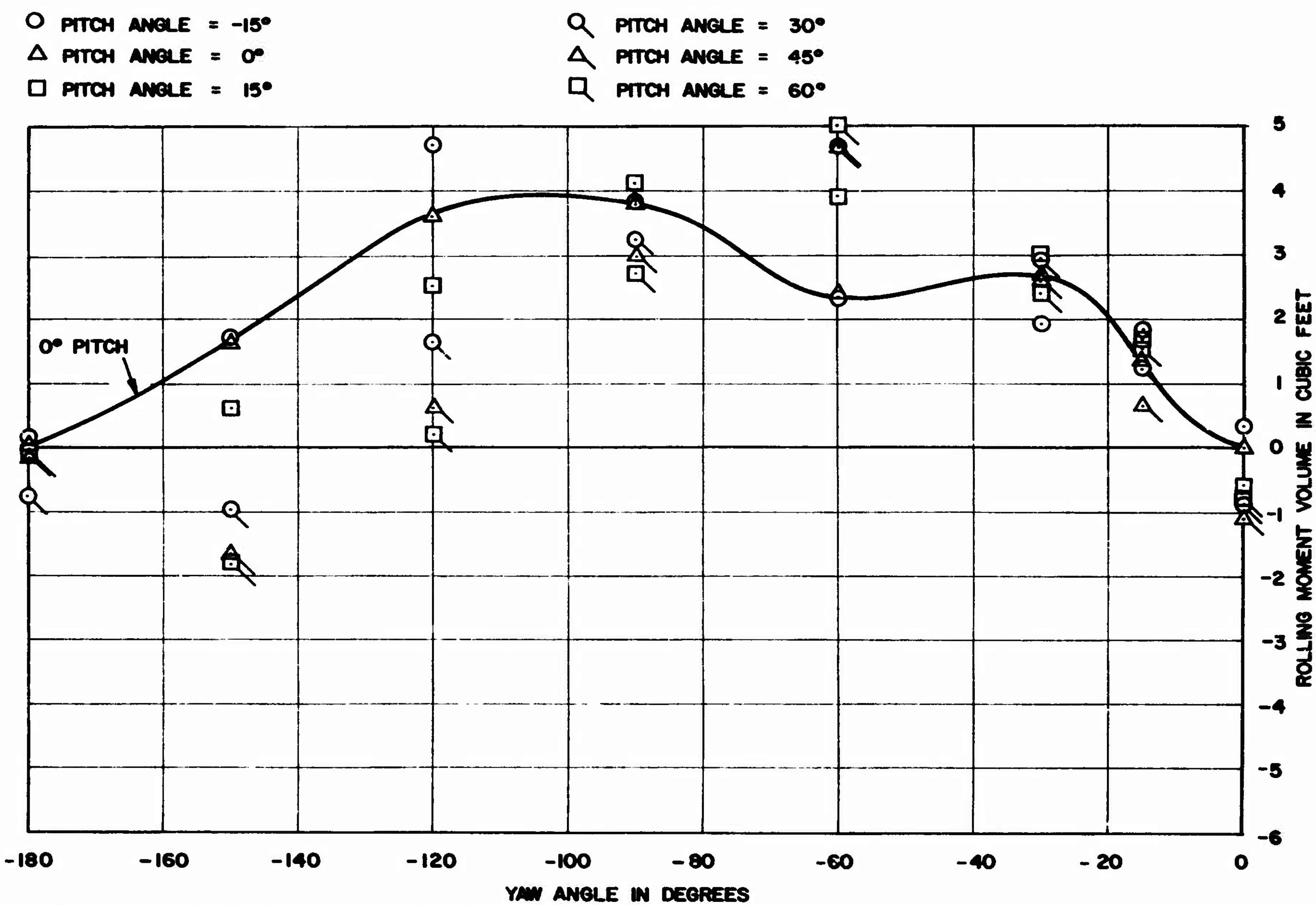


FIGURE 35 ACES II SEAT ROLLING MOMENT VOLUME AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES.
SUBJECT: 5% ANTHROPOMORPHIC DUMMY; $q = 30\ LB/FT^2$.

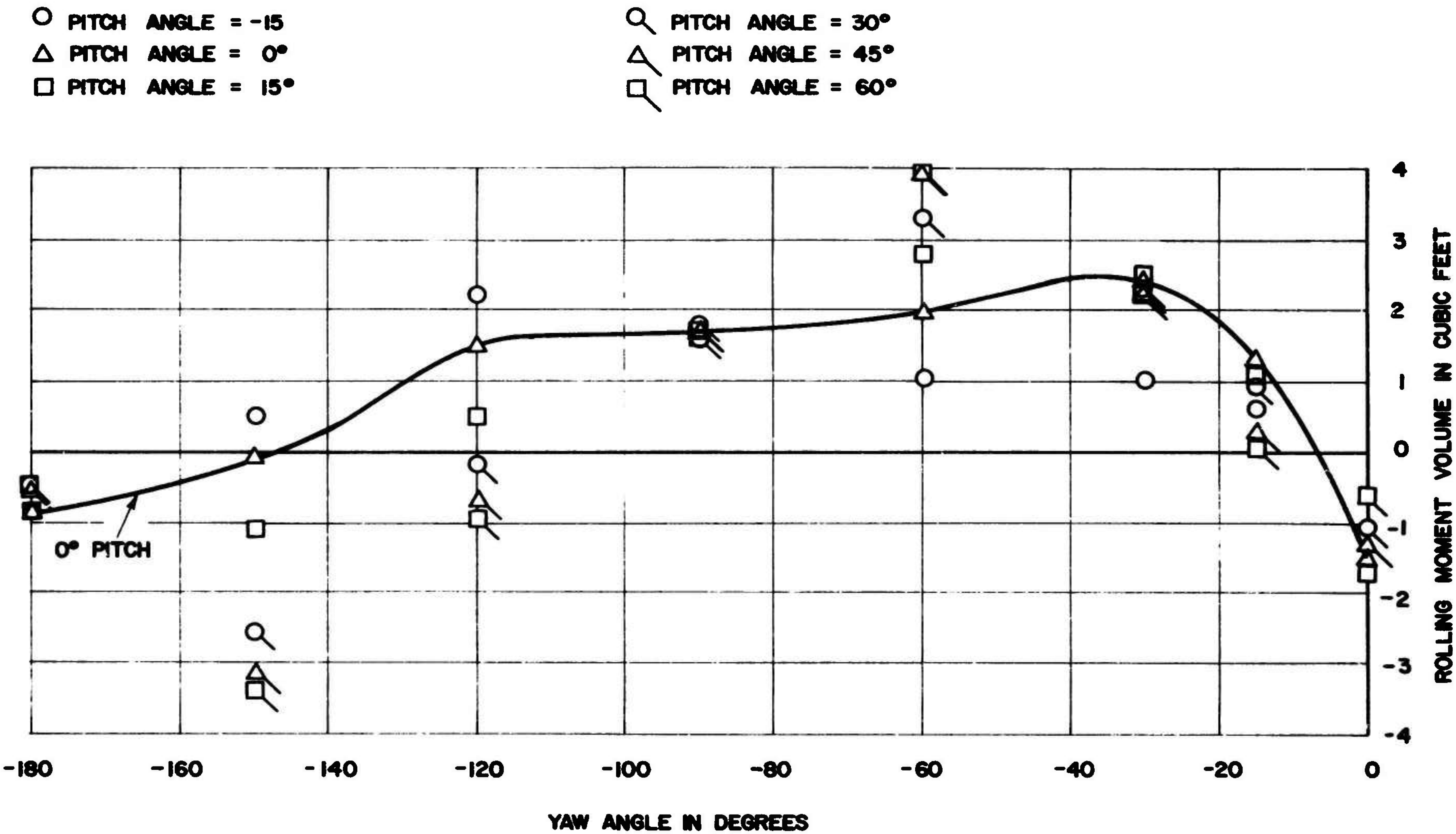


FIGURE 36 ACES II SEAT ROLLING MOMENT VOLUME AS A FUNCTION OF YAW ANGLE FOR VARIOUS PITCH ANGLES. SUBJECT: 95% ANTHROPOMORPHIC DUMMY; $q = 30\ LB/FT^2$.

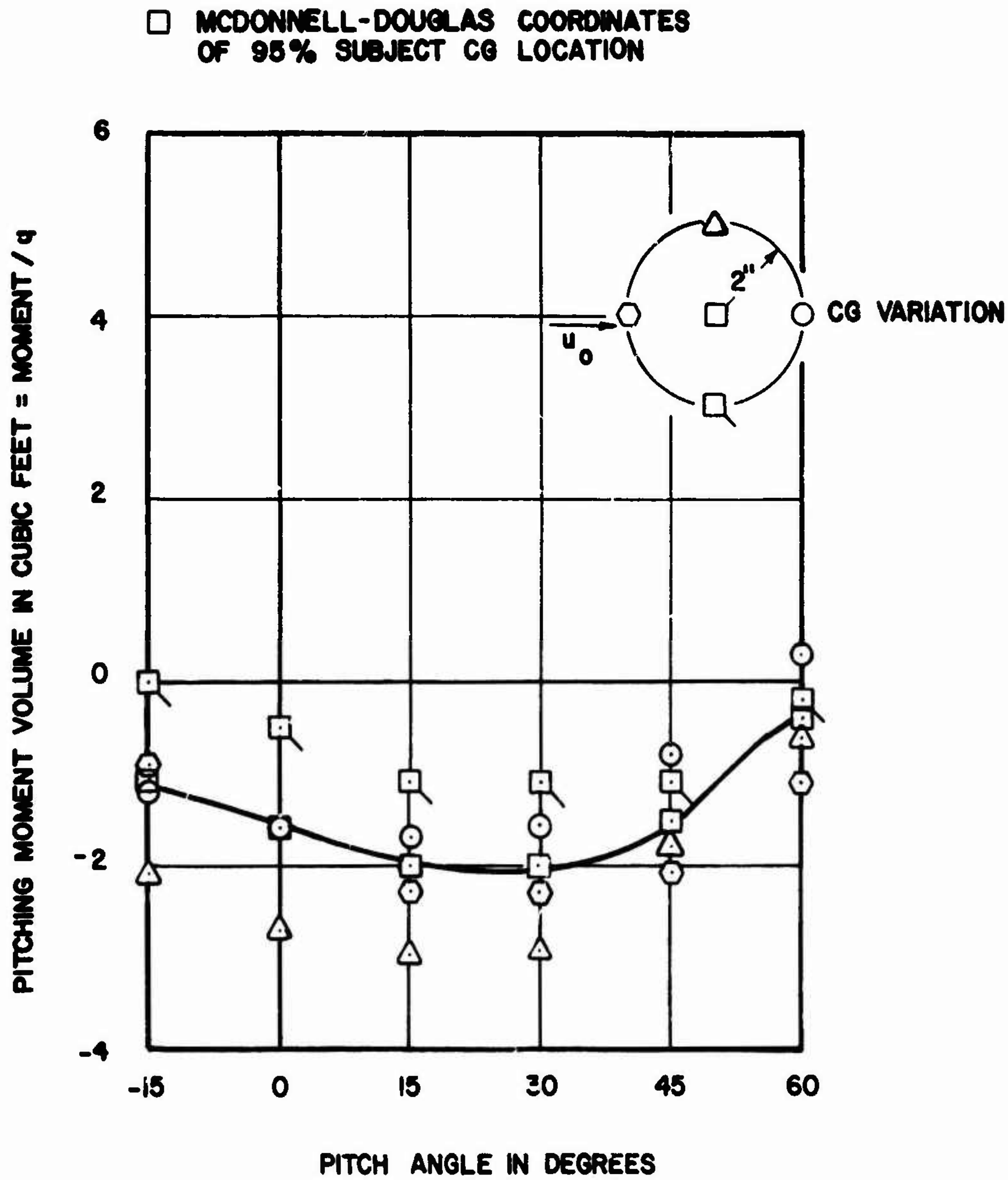


FIGURE 37 ACES II SEAT PITCHING MOMENT VS PITCH ANGLE FOR VARIOUS CG LOCATIONS, YAW ANGLE = 0°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

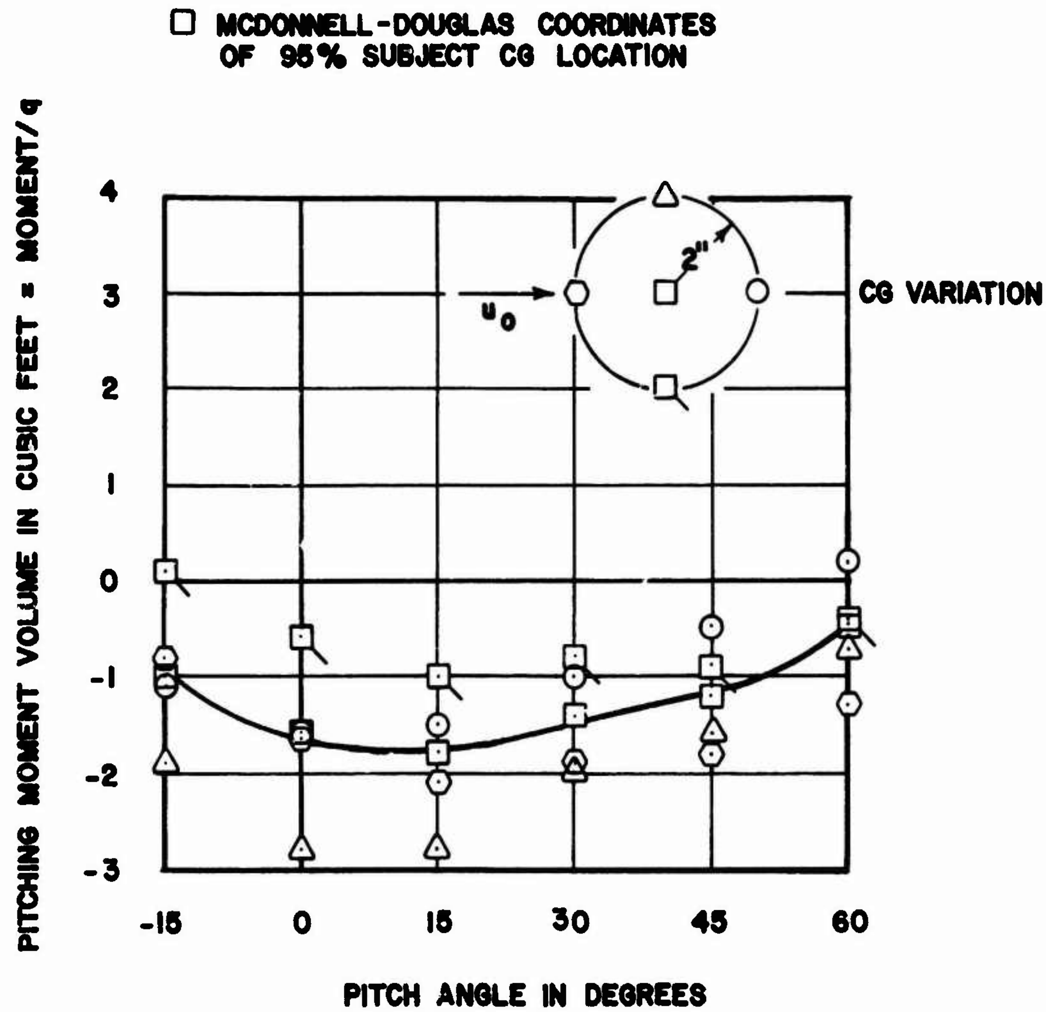


FIGURE 38 ACES II SEAT PITCHING MOMENT VS. PITCH ANGLE FOR VARIOUS CG LOCATIONS.
YAW ANGLE = -15°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

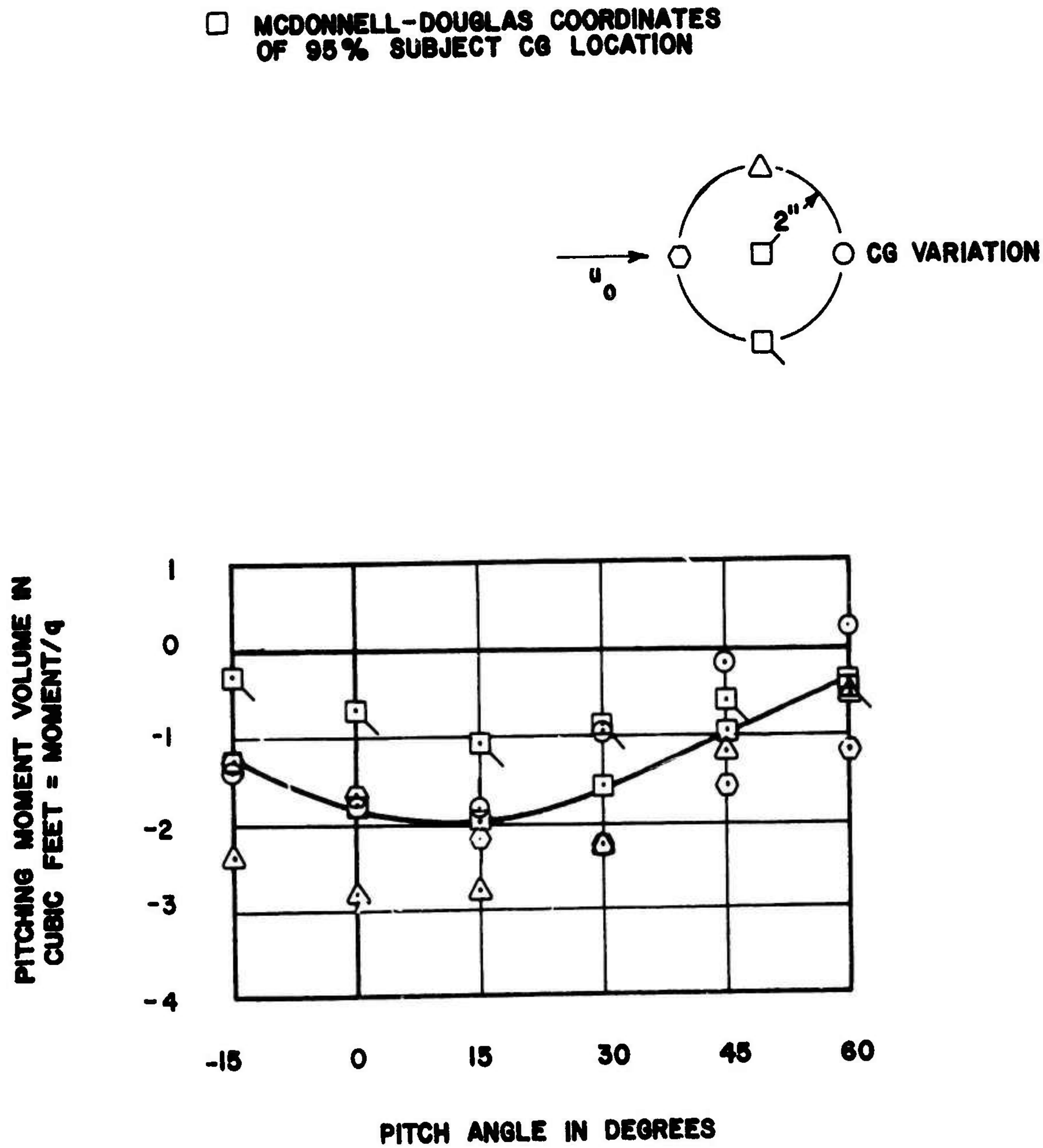


FIGURE 39 ACES II SEAT PITCHING MOMENT VS. PITCH ANGLE FOR VARIOUS CG LOCATIONS.
YAW ANGLE = -30°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

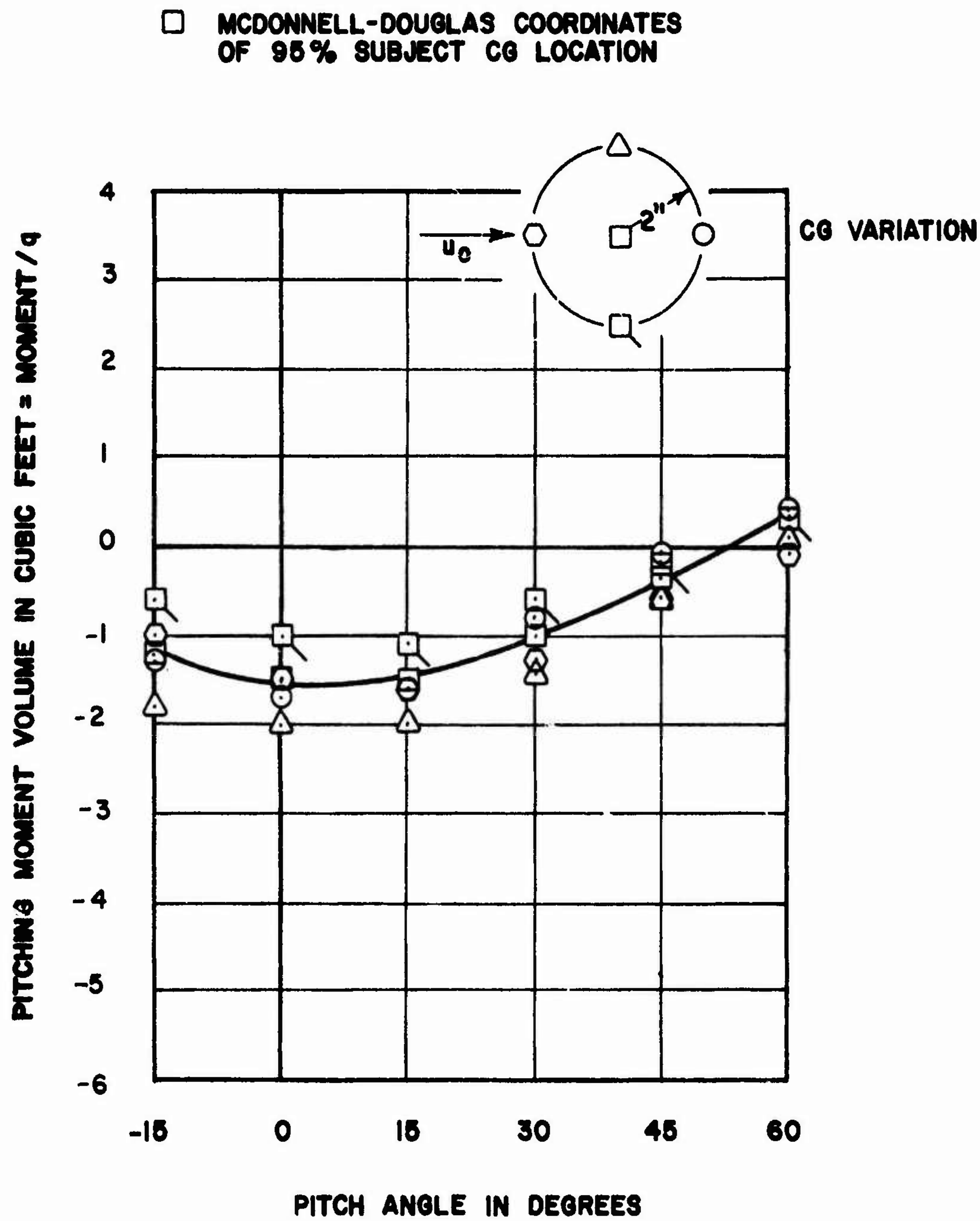


FIGURE 40 ACES II SEAT PITCHING MOMENT VS. PITCH ANGLE FOR VARIOUS CG LOCATIONS.
YAW ANGLE = -60°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

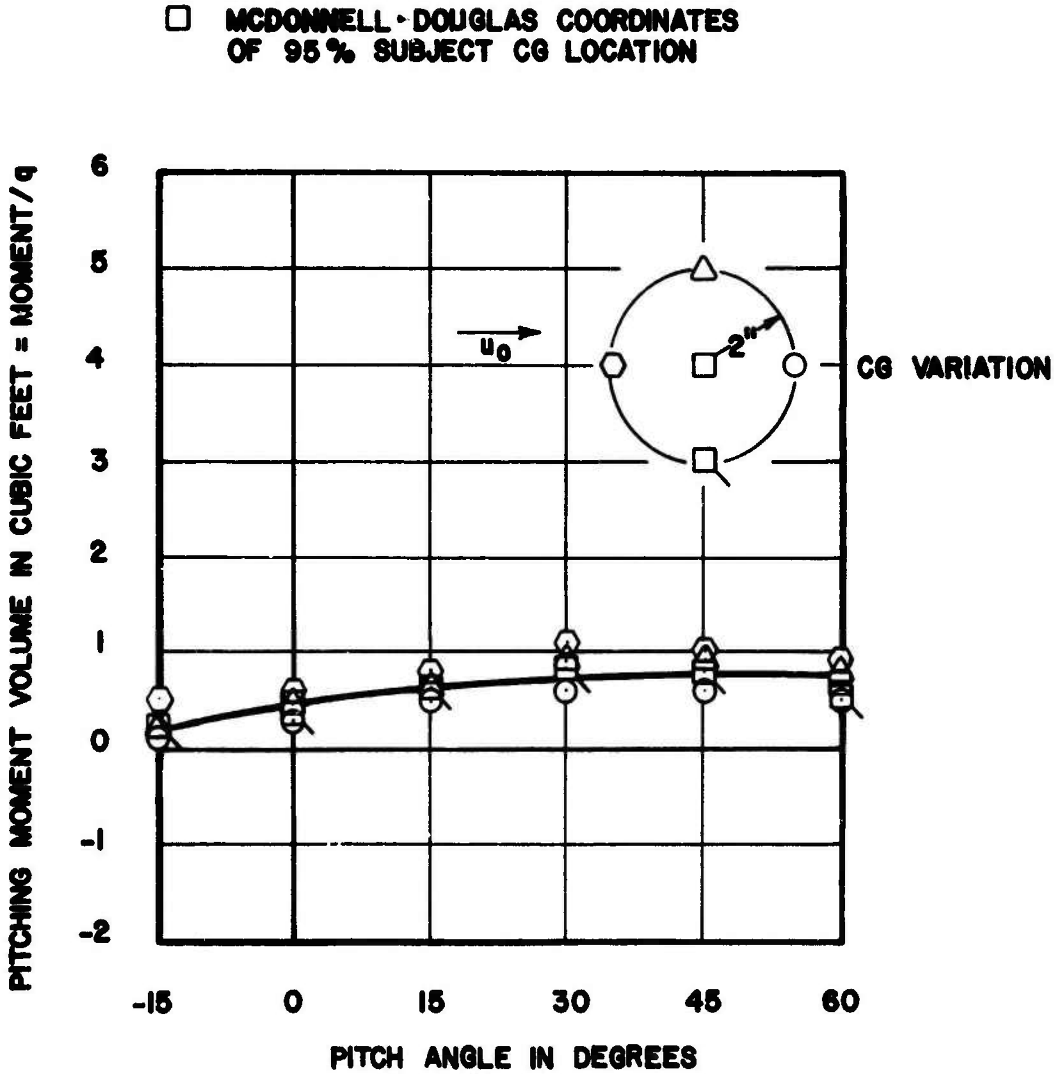


FIGURE 41 ACES II SEAT PITCHING MOMENT VS. PITCH ANGLE FOR VARIOUS CG LOCATIONS.
YAW ANGLE = -90°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

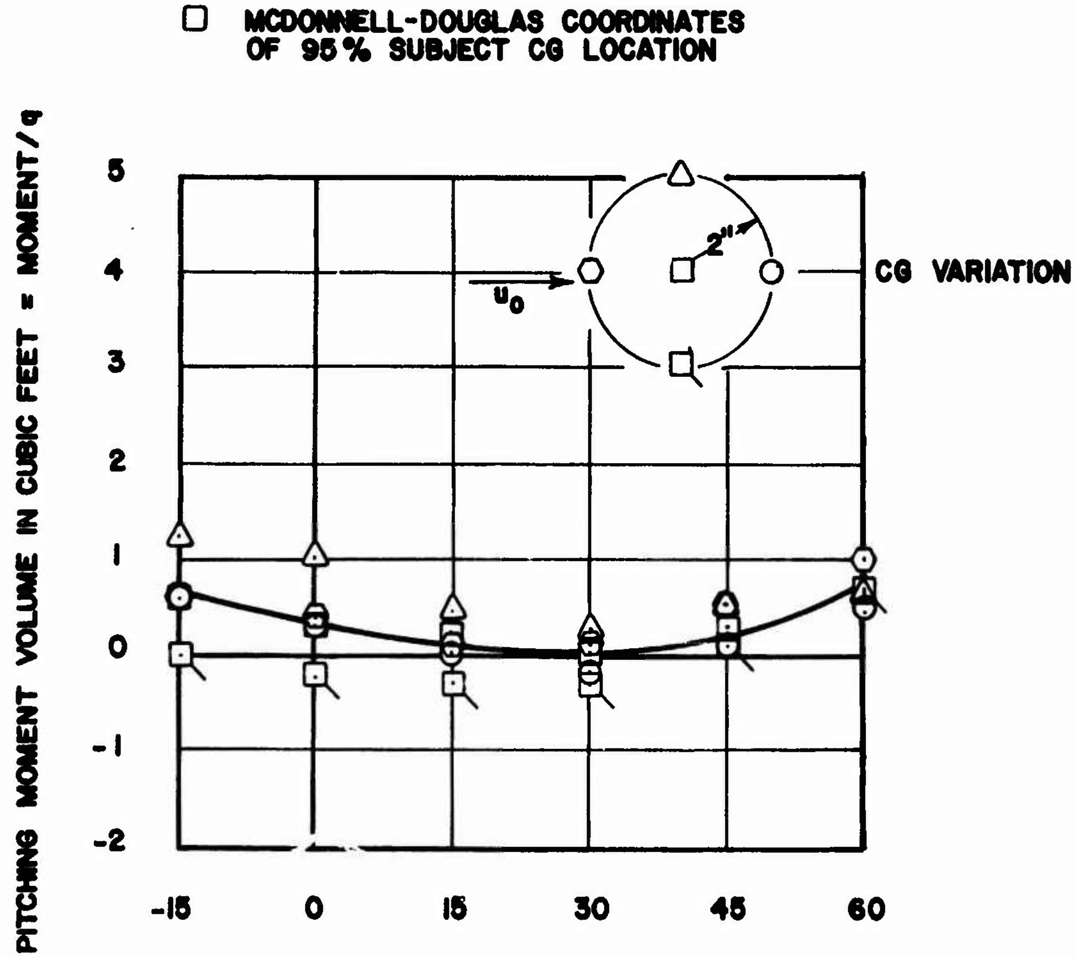


FIGURE 42 ACES II SEAT PITCHING MOMENT VS. PITCH ANGLE FOR VARIOUS CG LOCATIONS.
YAW ANGLE = -120°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

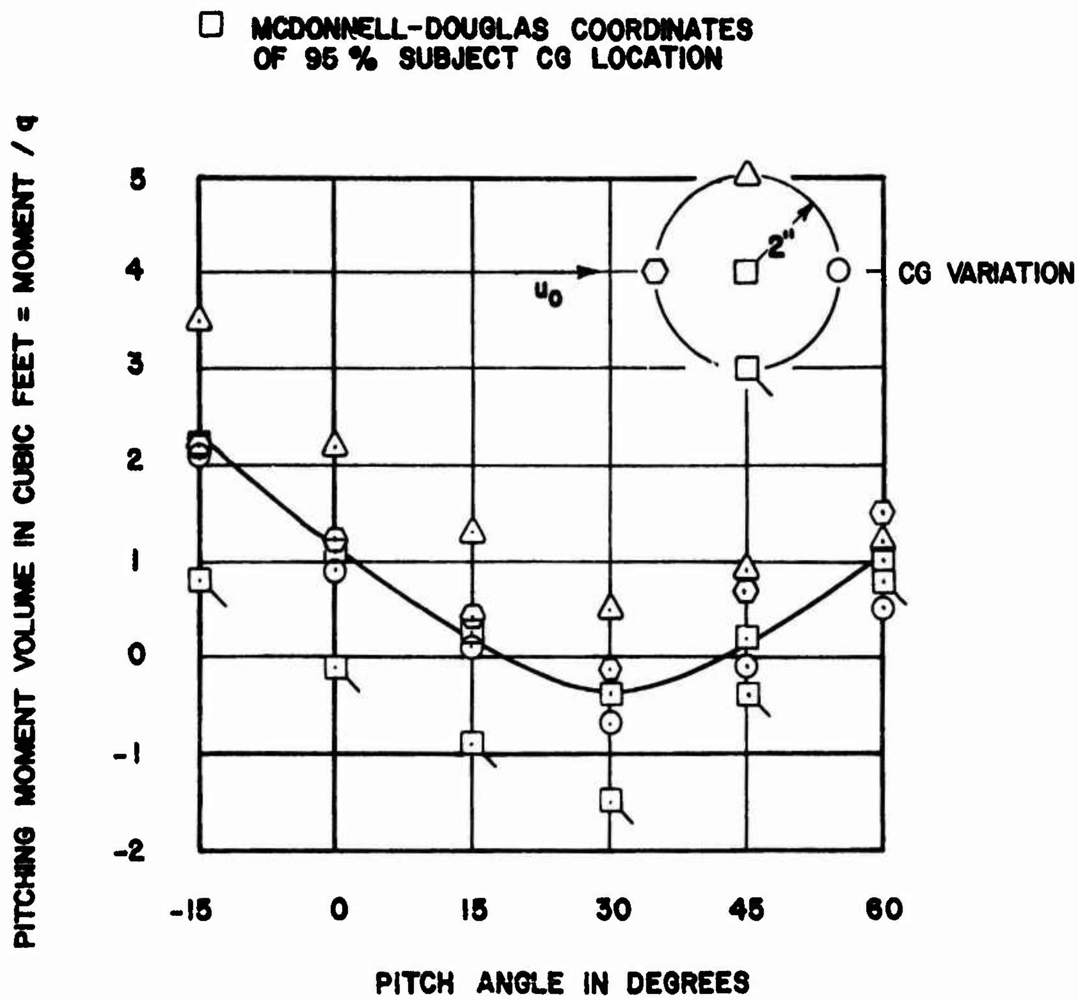


FIGURE 43 ACES II SEAT PITCHING MOMENT VS. PITCH ANGLE FOR VARIOUS CG LOCATIONS.
YAW ANGLE = -150°; SUBJECT: 95 % ANTHROPOMORPHIC DUMMY.

□ MCDONNELL-DOUGLAS COORDINATES
OF 95% SUBJECT CG LOCATION

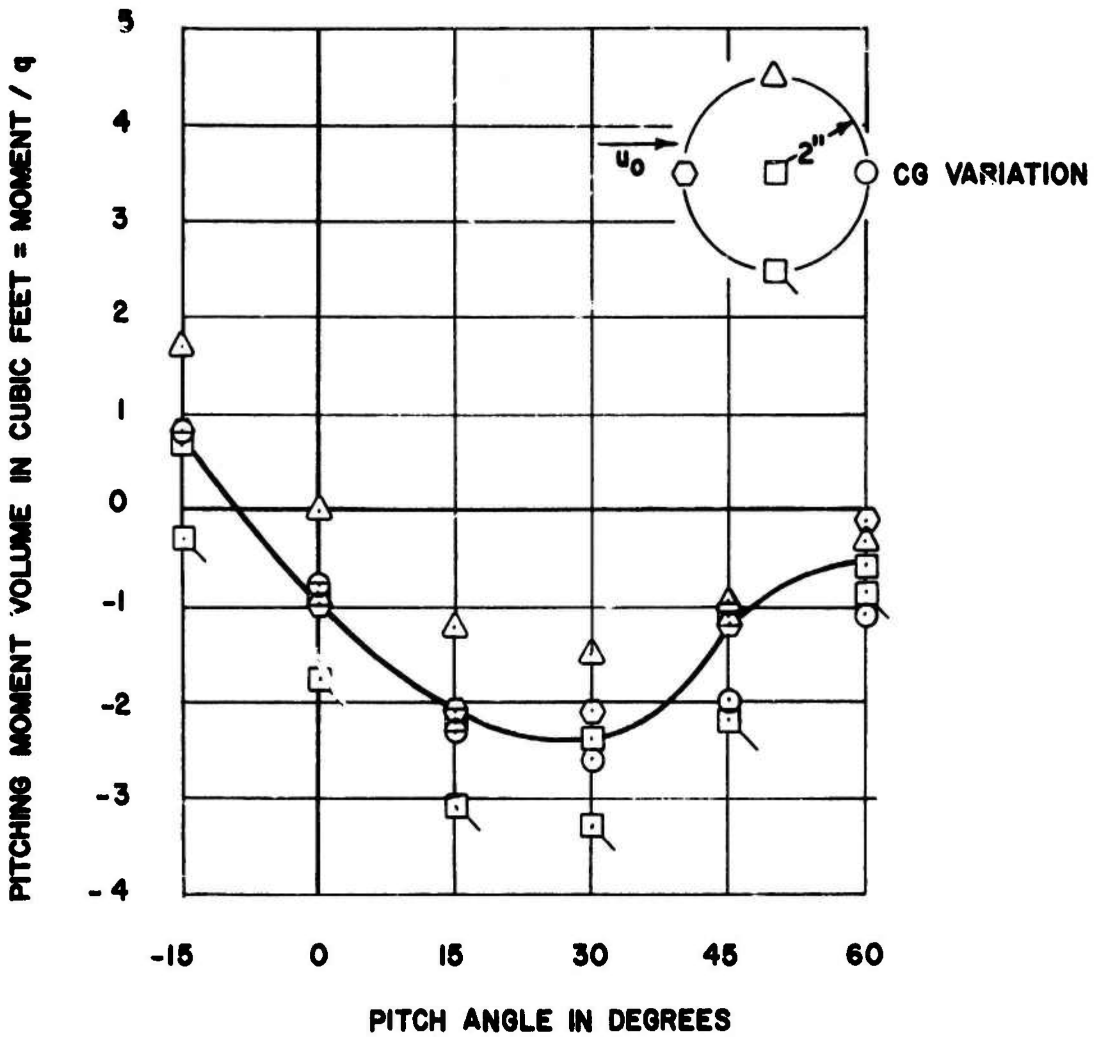


FIGURE 44 ACES II SEAT PITCHING MOMENT VS. PITCH ANGLE FOR VARIOUS CG LOCATIONS.
YAW ANGLE = -180°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

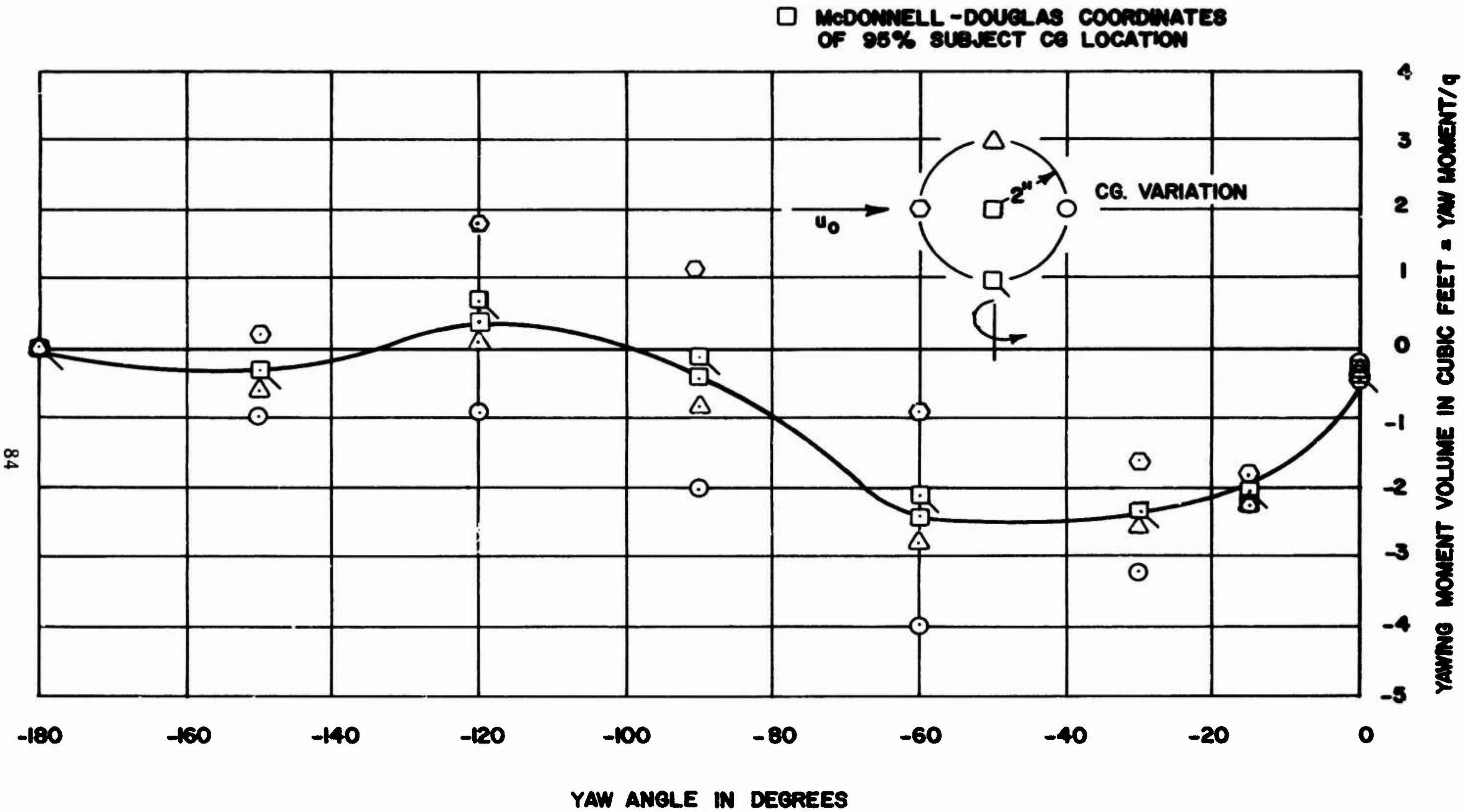


FIGURE 45 ACES II SEAT YAWING MOMENT VS. YAW ANGLE FOR VARIOUS CG LOCATIONS. PITCH ANGLE = -15°; SUBJECT: 95° ANTHROPOMORPHIC DUMMY.

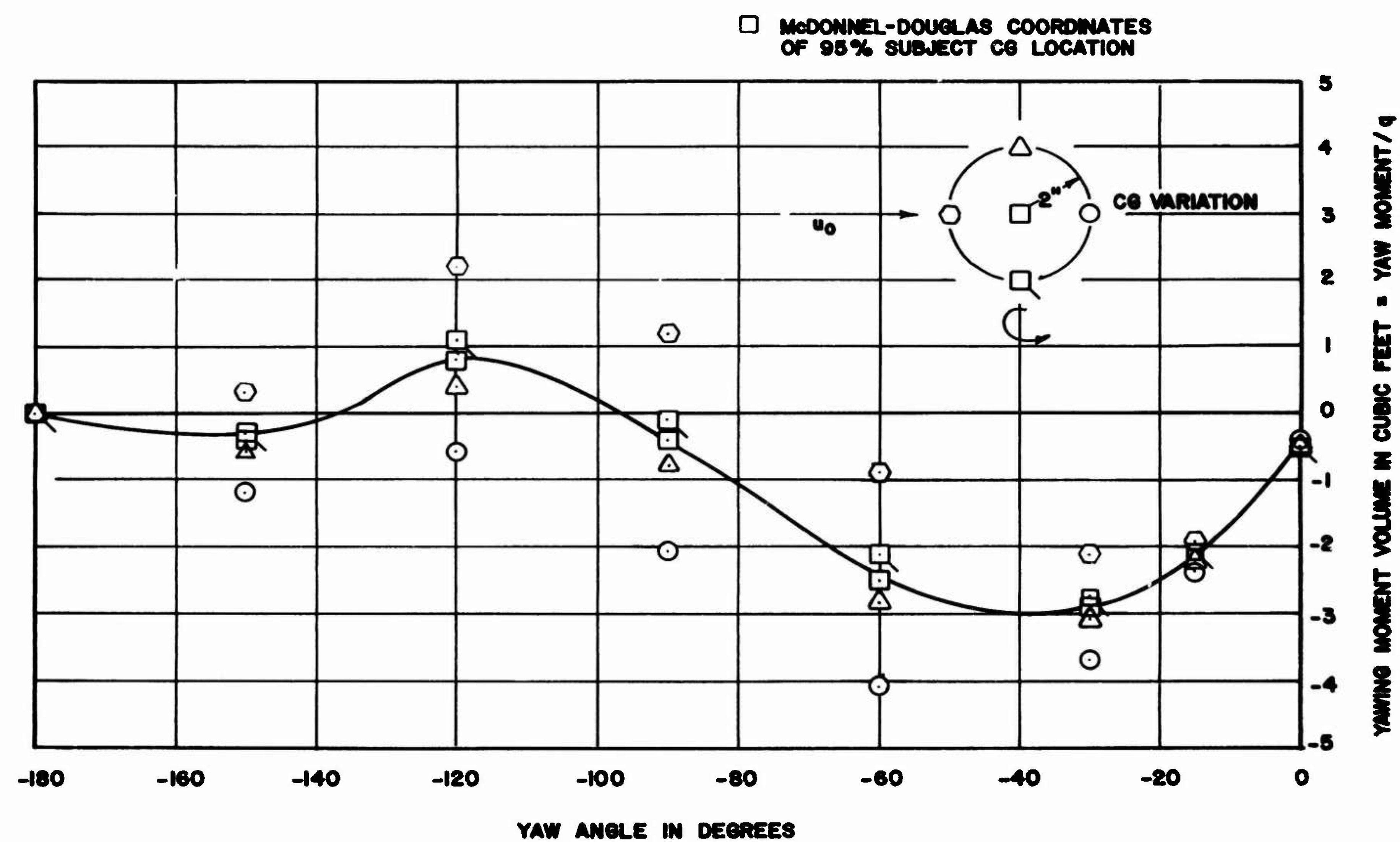


FIGURE 46 ACES II SEAT YAWING MOMENT VS. YAW ANGLE FOR VARIOUS CG LOCATIONS. PITCH ANGLE = 0°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

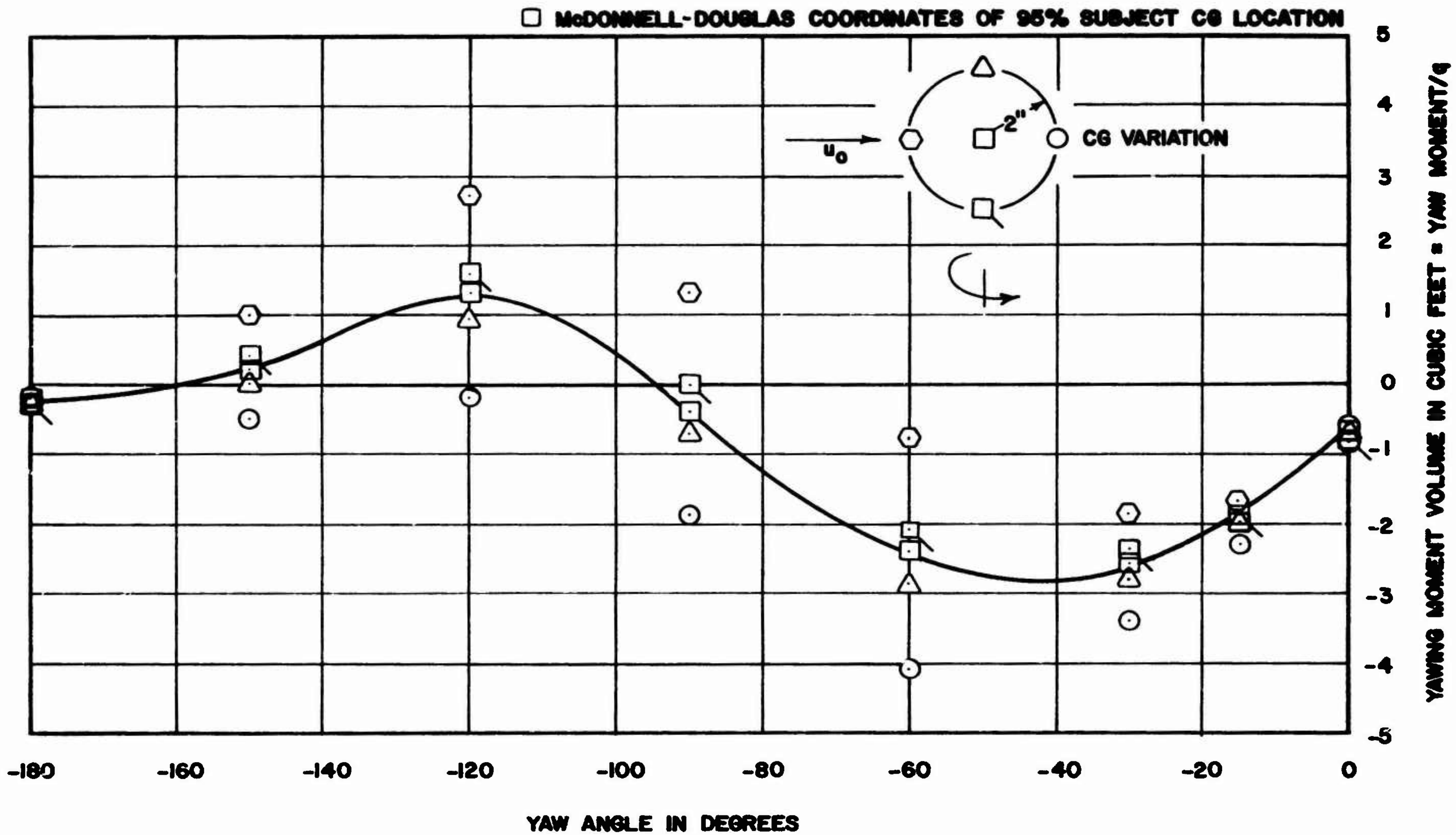


FIGURE 47 ACES II SEAT YAWING MOMENT VOLUME VS. YAW ANGLE FOR VARIOUS CG LOCATIONS.
PITCH ANGLE = 15° ; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

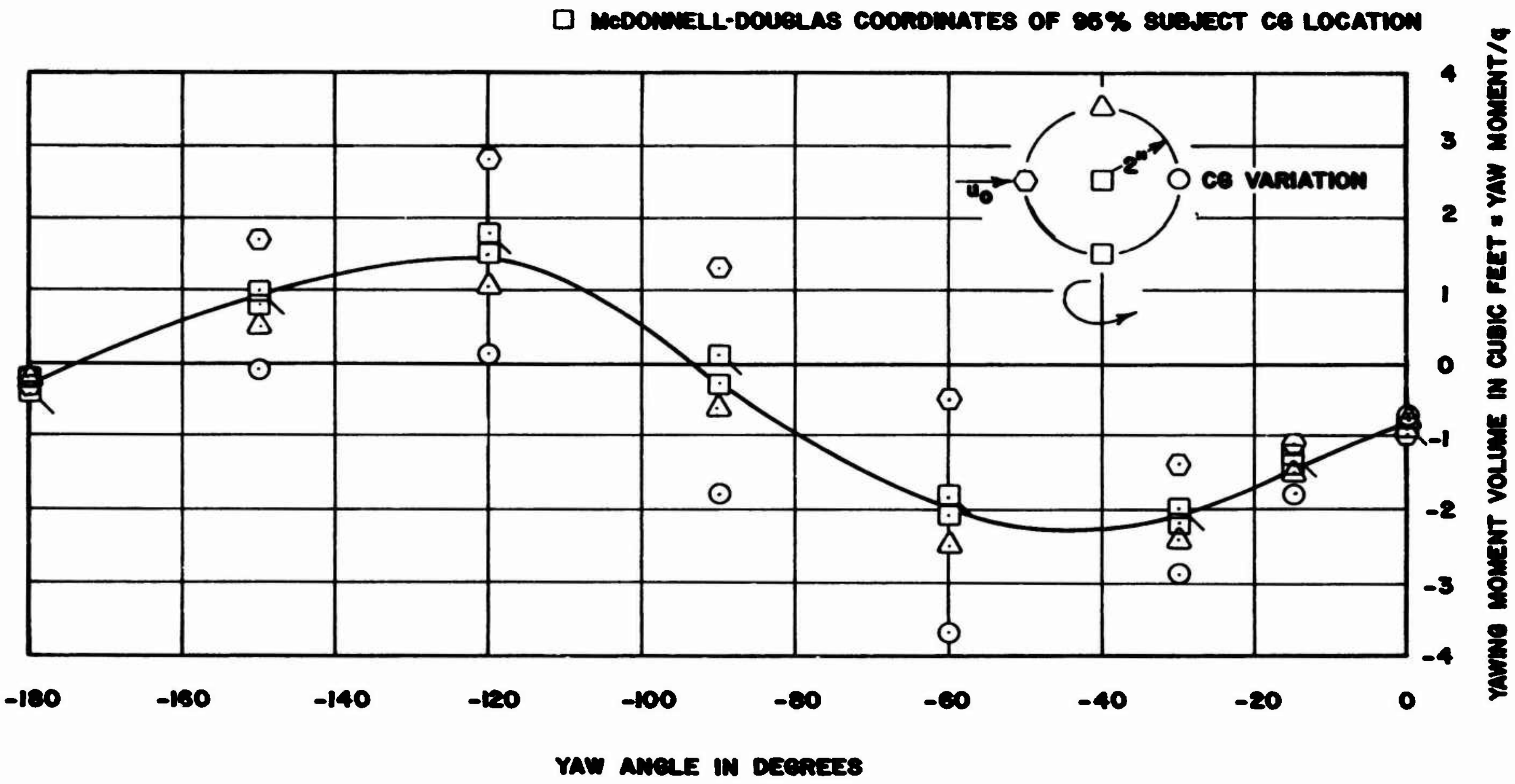


FIGURE 48 ACES II SEAT YAWING MOMENT VS. YAW ANGLE FOR VARIOUS CG LOCATIONS.
PITCH ANGLE = 30°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

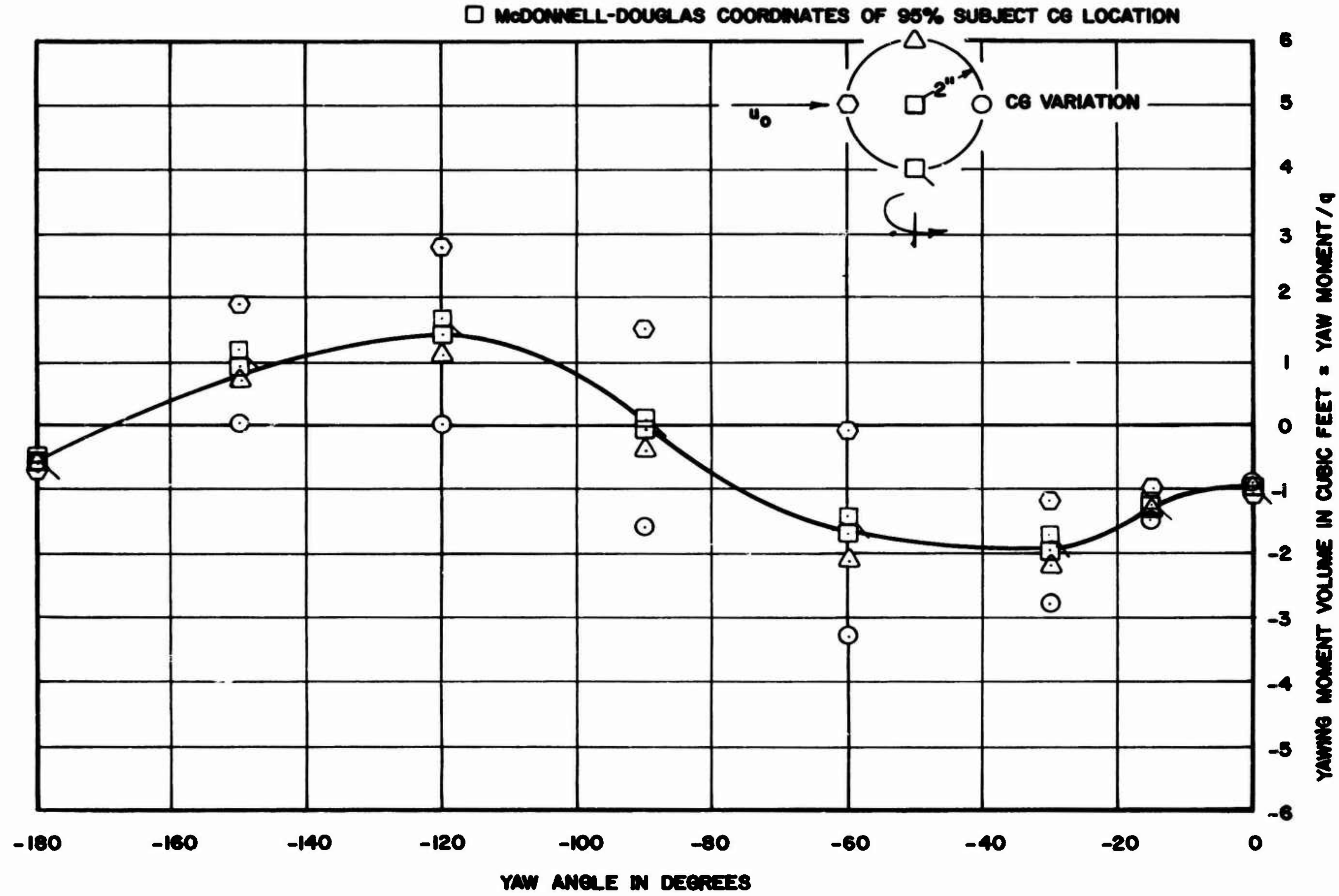


FIGURE 49 ACES II SEAT YAWING MOMENT VS. YAW ANGLE FOR VARIOUS CG LOCATIONS. PITCH ANGLE = 45°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

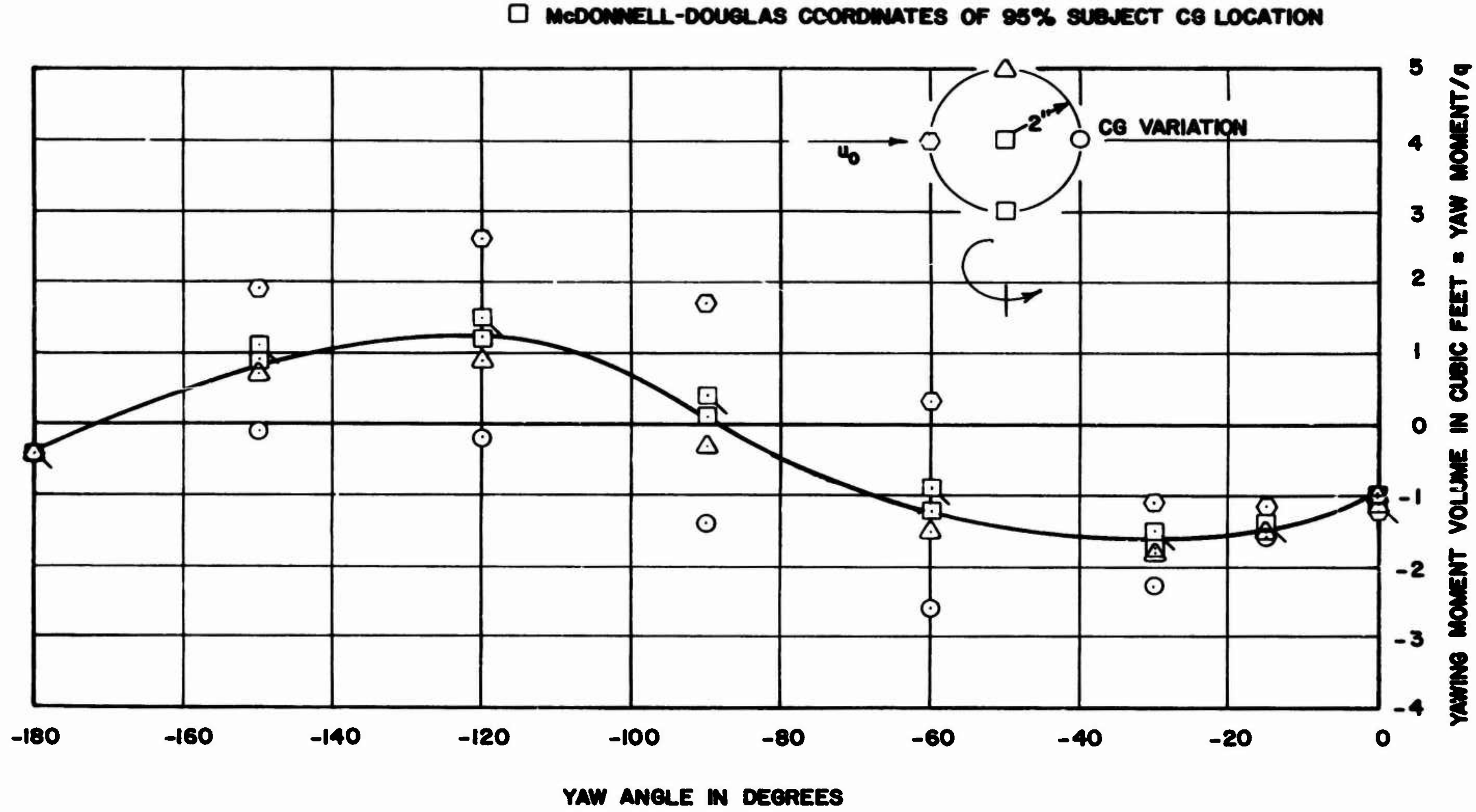


FIGURE 50 ACES II SEAT YAWING MOMENT VS. YAW ANGLE FOR VARIOUS CG LOCATIONS.
PITCH ANGLE = 60°; SUBJECT: 95% ANTHROPOMORPHIC DUMMY.

moment-angle relationship we require $M = 0$ and $\partial M/\partial\theta < 0$ in both pitch and yaw. Stability in roll has not yet been considered a requirement.

The seat is considered to be statically stable if the slope is distinctly negative over the range of ejection attitudes. Reference to the test results shows that this is seldom if ever the case. In many conditions such as those of Figures 22 and 24, the slope in the yaw range $-30° < \theta < 0$ is strongly positive, indicative of yaw instability (Figure 22). At best, a condition of neutral stability is indicated by Figure 24, where the pitch slope is more or less zero over a limited range of yaw angles. Even after trim adjustment has been made by CG movement or rocket thrust or other device, the seat has to be rated as unstable over the effective ranges of the input angles.

The static stability criteria are not sufficient to determine whether or not a state of motion, spinning, tumbling, or oscillating in any or all the six degrees of freedom can occur or will be sustained if it does. The influence of inertial terms and derivatives with respect to time-dependent quantities has to be included in the general equations. Moreover, static moments can be adjusted to zero only at a small, finite, even number of attitudes of pitch and yaw, with stable and unstable positions alternating. Thus stability can be achieved only over a limited range of angular attitudes.

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